The intent of this Technical Guide is to allow transformer manufacturers—and their designers and engineers—access to all technical information required to assist them in designing transformers using the Waukesha® UZD® Load Tap Changer. The information contained in this document is meant to be general and does not cover all possible applications. Any specific application not included should be referred directly to SPX Transformer Solutions, Inc. (including Waukesha® Components) or its authorized representative.

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Table of Contents

GENERAL DESCRIPTION
CONSTRUCTION
LTC Tank Oil-Filled Compartment – Tap Changer Live Parts...6-11
Epoxy Phase Moldings ..............................................6-7
Arcing Tap Switch (Tap Selector Switch) .......................8
Reversing Change-Over Selector (Reversing Switch) ..........8
Transition Resistors .................................................10
LTC Tank Air-Filled Compartment–Spring Drive Mechanism . 12-15
Drive ......................................................................12
Flywheel ..................................................................12
Geneva Gear ..............................................................14
Reversing Change-Over Selector Geneva Gear ...............14
UZD® Tank - External ............................................. 16-19
Weight and Dimensions ........................................... 16-17
Tank and Accessories .............................................. 18-19
BUE Motor Drive Mechanism .................................. 20-27
Cabinet ..................................................................20
Heater ......................................................................20
Gearing .....................................................................20
Motor .......................................................................20
Hand Crank .................................................................24
One-turn Shaft ............................................................24
Position Indicator .......................................................24
Mechanical and Electrical End Stops .........................24
Contact Device .........................................................24
Continuation Contact (84C) ....................................24
Maintaining Contact .................................................24
Interlocking Contact .................................................24
Auxiliary Contact ......................................................24
Brake ......................................................................24
Indicator Flag .............................................................26
Maintaining Contact Brake ......................................26
Start Contact .............................................................26
Operation Counter ....................................................26
Controls ....................................................................26
Protection ...................................................................26
Over-current Blocking ..............................................26
Indication ..................................................................26
Wiring and Connections ...........................................27
Optional Accessories ...............................................27

OPERATING PRINCIPLES
Load Tap Changer .....................................................28-33
Switching Sequence ................................................28
Arcing Tap Switch (Tap Selector Switch) .....................28
Reversing Change-Over Selector for Plus/Minus Switching...31
Through-positions ...................................................31
Schematic Diagram ................................................33
Motor Drive Mechanism ...........................................33-37
Operational Description – Schematic .........................33-35
Contact Timing Diagram ..........................................36
Local Control ...........................................................36
Remote Control ........................................................36
Automatic Operation Local Mode ................................36
Over Current Relay ..................................................37
Through-positions ..................................................37
Step-by-Step Operation ............................................37

TECHNICAL DATA & CHARACTERISTICS
Ratings - Insulation Level .........................................38
Transition Time .........................................................39
Standards and Testing .............................................39
Rating Plate ..............................................................39
Step Voltage and Through Current ................................40
Mechanical Life .........................................................40
Contact life ...............................................................40
Reverse Power Flow ................................................40
Short Circuit Strength ...............................................40
Loading Beyond Nameplate ......................................40
General Description

The UZD® is an externally mounted load tap changer intended for application on liquid-filled power transformers for varying the transformer's turns ratio while energized and carrying load. UZD® is a three phase, fully insulated, 33 position switch designed for plus/minus operation by use of a reversing change-over selector switch. UZD® is a “High Speed Resistance Bridging (Transition)” Tap Changer, meaning it employs a resistor for the transition impedance, limiting the circulating current in the bridging position when two adjacent taps are bridged during a tap change operation. The arcing that occurs during a tap change operation takes place in the insulating liquid. An on-line oil filtration system is recommended to keep the oil clean, increase reliability and extend maintenance cycles.

To increase contact life and reduce maintenance, the WAUKESHA UZD® load tap changer has separate arcing contacts and main current-carrying contacts on the same moving arm. With the Waukesha UZD®, all arcing is shunted across three sets of rolling contacts and stationary arcing contacts. The stationary arcing contacts are made of special arc-resistant alloys. There is no arcing across the main current-carrying contacts.

The UZD® is designed to be mounted on the outside of the transformer tank. All equipment necessary to operate the tap changer is contained in this compartment and the attached BUE motor drive mechanism. This arrangement allows the transformer tank to be designed significantly smaller than a transformer with the load tap changer mounted inside the transformer tank (less plate steel and less oil). This arrangement also allows for simpler transformer assembly. The voltage regulating relay is provided by the transformer OEM and typically mounted in the main transformer control cabinet.

The UZD® has two compartments: the oil filled switching compartment on the left hand side, which houses the tap selector and the reversing change-over selector, and the air-filled compartment on the right hand side which houses the spring drive mechanism.

The WAUKESHA UZD® LTC compartment holds 100 gallons of oil. The WAUKESHA UZD® LTC oil compartment is designed with a sloped sump at the bottom of the compartment and a lip on the front door. Thus, all the oil can be drained from the compartment and oil does not spill out when you open the front door. Also, cleaning the inside of the tap changer (spraying oil to clean the contacts, for example) can be done easily with the door open. The oil drains through the drain valve at the bottom of the sump.

The BUE motor drive mechanism is a separate compartment mounted below the spring drive mechanism at eye level with a driveshaft connecting the motor drive mechanism to the spring drive mechanism. The cabinet utilizes a split, half-box cover design for easy access to the interior. All wiring points which might be of interest to the user should be wired to the main control cabinet by or the transformer OEM. This reduces wiring time in the field.

The WAUKESHA UZD® LTC utilizes a spring-loaded drive mechanism to make all tap position changes. The main drive motor charges the spring battery which makes the tap change—not the motor itself. This drive mechanism design limits arcing time to about 6 milliseconds with a total time to change taps of approximately 70 milliseconds. The spring drive also insures that if control power is lost or the motor fails, the LTC will not remain in an off-contact position. Furthermore, the Geneva gear drive system in the spring drive compartment of the Waukesha UZD® assures that for one full revolution of the fly wheel (connected to the spring battery), the contact arm will move only 1/18 of a revolution providing positive contact alignment on each tap position. The motor takes approximately 6 seconds to charge the spring battery.
The WAUKESHA UZD® LTC may be manually operated under load. Thus, with a loss of power to the motor, the Waukesha UZD® is still capable of changing tap positions by manual operation of the crank handle which charges the spring-loaded drive mechanism defined in the previous paragraph. The speed at which the hand crank is turned manually has no bearing on the speed at which the contacts move on the Waukesha UZD® as this is determined by the energy stored in the spring drive. When the spring battery is moved past top dead center, the tap change will occur at normal speed regardless of hand crank speed.

UZD® conforms to IEEE C57.131-1995 and IEC 60214-1.
**Construction**

Epoxy Phase Molding

Three (one per phase) one-piece, cast Epoxy Phase moldings Figure 2, mount inside the liquid filled compartment. The Tap selector switch assembly, Reversing change-over selector switch (reversing switch) assembly and the Transition resistors are mounted on these Phase moldings. Bearings for the operating shafts of the Moving tap selector switch and the Reversing change-over selector switch are also embedded in the phase moldings. These Phase moldings are sealed to the back of the tap changer tank with O-ring gaskets in a recessed gasket groove molded into the epoxy. The Phase moldings are held in place against the back wall with studs, nuts and clamps.

The gasket prevents oil exchange between the UZD® oil and the transformer oil. Copper rods are embedded in the Phase moldings and allow the Phase moldings to act as bushings, connecting contacts in the liquid filled compartment with cables in the transformer tank.

**LTC TANK - OIL COMPARTMENT - TAP CHANGER LIVE PARTS**

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The diagram illustrates the various components and labels, including:
- **FLANGE FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **OIL LEVEL INDICATOR**
- **PRESSURE RELAY**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **DRAIN**
- **TRANSITION RESISTOR**
- **SWITCHING COMPARTMENT**
- **FLANGE FOR OPTIONAL UPPER FILL VALVE**
- **FLANGE FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **SPRING DRIVE MECHANISM**
- **INLET PIPE FOR OIL FILTRATION**
- **BUE MOTOR DRIVE MECHANISM**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
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- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
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- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
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- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
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- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
- **WELL FOR OPTIONAL RAPID PRESSURE RISE RELAY**
- **WELL FOR OPTIONAL UPPER FILL VALVE**
- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
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- **WELL FOR OPTIONAL PRESSURE RELIEF DEVICE**
- **WELL FOR OPTIONAL TEMPERATURE PROBE**
The transformer manufacturer connects winding leads to these terminals of the Phase molding, without requiring opening of the tap changer. Connections are made from inside the transformer tank after the core and coil assembly has been fitted and prior to oil filling. The terminals are numbered for proper identification. These connections are made via a special crimp-on cable connector supplied with the UZD®. There are different sized connectors to fit different cable sizes. The transformer OEM must specify the cable size.

On each Phase molding, 18 Stationary contact assemblies are mounted in a circle Figure 2, Item 2. The Moving contacts Figure 2, Item 3 of the Tap selector switch assembly are mounted on a drive shaft running through the center of the Phase molding. At the top of the Phase molding are the two Stationary reversing change-over selector contacts Figure 2, Item 5 and the Moving reversing change-over selector switch assembly Figure 2, Item 6 mounted on a drive shaft running through a bearing in the Phase molding. Adjacent to each of the two drive shafts is a Slip contact (bowtie contact) Figure 2, Item 4 assembly that transfers the current from the moving contacts to the copper rods in the Phase moldings.
Arcing Tap Switch (Tap Selector Switch)
The Tap selector switch consists of the Stationary contacts Figure 3 mentioned above and a Moving contact assembly Figure 4. The Stationary contacts are mounted on a bracket which is secured to terminals embedded in the Phase moldings. There are two operating sections of the Stationary contacts. The middle section of the contact is constructed of silver-plated copper and is where the moving contacts rest when the tap changer is in the “on” position. The leading and trailing edges of the Stationary contacts are copper-tungsten arcing tips brazed on to the copper body prior to silver plating and mate with the moving copper/tungsten arcing roller contacts during a tap change operation. All arcing happens on this area of the stationary contacts and the arcing roller contacts.

The Moving contact system consists of the main current carrying contact Figure 4, Item 2, the Main switching contact Figure 4, Item 3 and two Transition contacts Figure 4, Item 4. The center contacts are insulated from the two outer contacts and built together as a rigid unit rotated by a common drive shaft. The three phase drives are inter-linked phase-to-phase by epoxy couplings Figure 6, Item 5 that provide flexibility in alignment between phases. At the right end, the drive is connected through an oil seal to a Geneva gear in the air-filled spring drive compartment. The Geneva gear ensures correct indexing and locks the moving contacts in position at each tap. In the stationary operating position, the through current is carried by the main current carrying contact, which consists of two opposing contact fingers pressed onto the stationary contact by springs. The Main moving switching arcing rollers and the Transition arcing roller contacts roll up the ramp shape of the arcing tip brazed into the Stationary contacts. The making and breaking takes place between the stationary and moving roller contacts.

Current collected by the main moving contacts passes directly to a slip contact (bowtie contact) Figure 2, Item 4 near the center of the Phase molding, and goes back to the transformer through bus bars embedded in the Phase molding.

Reversing Change-Over Selector (Reversing Switch)
Each phase includes a single pole, double throw Reversing change-over selector (reversing switch) near the top of each Phase molding Figure 5. This slow speed switch is arranged by internal drive gearing to change over at a circuit position where it does not carry current. The Reversing moving contacts Figure 5, Item 2 are driven by the Motor drive mechanism through a Geneva gear connected by a Reversing drive shaft Figure 5, Item 3 which enters the liquid filled space through an oil seal. The Geneva gear ensures correct indexing, and locks the moving contacts in position at each tap.

In order to effect self-cleaning of the contact surfaces, the movement of the reversing switch is arranged in three stages, during which the reversing switch does not make or break a current. In the first stage, the Reversing moving contact Figure 5, Item 2 wipes along the face of the Reversing stationary contact Figure 5, Item 1. In the second stage, the Reversing moving contact breaks with the Reversing stationary contact and makes with the edge of the other Reversing stationary contact. In the third stage, the Reversing moving contacts wipe the face of the Reversing stationary contact until reaching the final position. This wiping action is intended to keep the contacts clean of film buildup. The sequence is seen clearly in Figures 19A, 19B and 19C, page 32.

The reversing switch connects the regulating (tapping) winding to the main winding, such that the voltage generated in the regulating winding either adds to or subtracts from the voltage produced in the main winding. This doubles the duty of the stationary selector switch contacts and of the turns in the regulating (tapping) winding so that 16 taps produce 32 different voltages. See typical Connection Diagram, Figure 20D, page 33.
FIGURE 3: STATIONARY CONTACT

FIGURE 4: MAIN MOVING CONTACT ASSEMBLY WITH TRANSITION RESISTOR
**Transition Resistors**

The Transition resistors Figure 4, Item 1 are made from resistor wire wound on insulating bobbins. They are connected between the Main current carrying contact and the Transition arcing roller contacts and rotate with the selector switch. The resistance value is determined by the transformer design and will be selected by SPX Waukesha. Resistance valves are typically in the range of 0.1Ω to 5.0Ω.
ITEM 1
FLANGE FOR OPTIONAL INTEGRATED OIL FILTER PUMP MOTOR

ITEM 2
REVERSING SWITCH DRIVE MECHANISM

ITEM 3
SPRING DRIVE MECHANISM

ITEM 4
DRIVE SHAFT

ITEM 5
INSULATING EPOXY DRIVE COUPLING

ITEM 6
BUE MOTOR DRIVE
Drive

In the following paragraph, numbers in parentheses refer to item numbers in Figures 7A and 7B.

The Spring Drive Mechanism is housed in an air compartment on the right side of the UZD® (when facing the front of the UZD®). The spring drive accepts power from the BUE Motor Drive Mechanism mounted below it. This power is transmitted from the BUE to the spring drive via a Drive shaft (1) contained in a housing. The Drive shaft turns five revolutions per tap change and stores energy in a Spring battery (8) by putting the springs in tension. The Drive shaft (1) drives the Spring operator crank (6) through a right angle, conical Bevel gear set (2) and (3) with a 5:1 gear reduction. The Spring operator crank (6) rotates Drive pin (7) which charges the Spring battery (8) to discharge 90° without interference from the driving gear set. Once the Spring operator crank (winding eccentric cam) connected to the Spring battery passes top dead center, the springs will collapse and transmit their stored energy to a Flywheel (9). As the Spring operator crank charges the springs during its rotation, the Flywheel and Flywheel shaft (10) are driven by means of the Driving pin (7) so that the Disc brake (11) will be released just as the spring battery discharges. The Driving pin (7) moves within the length of a 150° backlash slot in the Flywheel (8). With continued driving, the springs are released and the Spring operator crank (6) quickly pulls the Flywheel around.

Flywheel

In the following paragraph, numbers in parentheses refer to item numbers in Figures 7A and 7B.

The Flywheel shaft (10) is held by a bearing mounted in support (15). The flywheel (9) is used to “even out” the spring battery energy to give a smooth contact movement and to ensure the same contact speed is maintained. The Flywheel movement does not need to stop simultaneously with the Spring operator crank but can continue within the Flywheel’s slot length. At the end of the tap change operation, excess energy is absorbed by a Disc brake (11) applied to the Flywheel. The Disc brake is operated by rollers that emerge from cam slots in the Flywheel to release the brake just as the spring battery discharges, and then roll back into the cam slots to reapply the break about 180° later.

If a fault occurs in the Springs (8), the operation is carried through directly by the motor.

There are two Geneva gears in the spring drive compartment. The first Geneva gear (13) drives the selector switch. The second Geneva gear (18) drives the Reversing change-over selector.

The Flywheel (9) turns one full revolution per tap change, into a Geneva gear (13). The Geneva gear principle is used to change the rotary motion into a stepping motion. The Geneva gear is also used to lock the moving contact system when in position.
FIGURE 7A: SPRING DRIVE MECHANISM

**LEGEND**

**ITEMS FOR FIGURE 7A AND 7B**

1) SHAFT COUPLING AND SHAFT
2) BEVEL GEAR (SMALL)
3) BEVEL GEAR (LARGE)
4) CAM SHAFT
5) GEAR DRIVE SUPPORT
6) SPRING OPERATOR CRANK
7) DRIVE PIN
8) SPRING BATTERY
9) FLY WHEEL
10) FLYWHEEL SHAFT
11) DISK BRAKE
12) GENEVA GEAR DRIVE
13) GENEVA GEAR
14) LTC SHAFT
15) DRIVE SUPPORT
16) BACKLASH COUPLING
17) GENEVA GEAR DIVE
18) GENEVA GEAR
19) CONTROL DISK
20) CHANGE-OVER ARM
21) COUPLING SHAFT
22) SHAFT
23) BEARING HOUSING
Geneva Gear

In the following paragraph, numbers in parentheses refer to item numbers in Figures 7A and 7B.

The Geneva gear drive (12) rotates both the Geneva gear (13) and selector switch shaft (14) one step. After this movement, which corresponds to one tap change operation, the Geneva wheel is locked by the control device on shaft (10). Shaft (14) goes through a bearing housing in Drive support (15) into the oil filled switch compartment. The bearing housing includes both bronze bearings and oil seals.

The energy necessary to make a tap change is delivered entirely from the Springs (8), independent of motor operation. The spring drive allows the speed of the selector switch to be independent of the external means of motive power, e.g. motor or manual crank handle. This feature allows the UZD® to be operated manually via the crank handle, even when the transformer is energized and fully loaded. In the event of an auxiliary power supply failure, the drive motor will stop and the spring battery will slowly relax or continue through the tap change (if the springs have already started to discharge). In either case, the selector switch and/or reversing switch will always be in the proper operating position.

Reversing Change-Over Selector Geneva Gear

Two drive shafts penetrate the wall between the air-filled spring drive mechanism compartment and the oil-filled switch compartment. One shaft (14) drives the selector switch and the other Shaft (22) drives the reversing change-over selector.

Referring to Fig. 7A and 7B, a cam is located at the end of shaft (4), which drives the backlash coupling (16), which drives a Geneva gear drive pin (17). The backlash coupling is freely mounted in support (5). The Geneva gear drive (17) rotates a Geneva gear (18) one step per tap change operation, after which the Geneva gear is locked by the center of the drive on the backlash coupling (16). The Geneva gear (18) with control disc (19) is freely mounted on a shaft which is fixed in support (5). The Control disk (19) prevents the change-over arm from moving until a neutral position is reached.

When the tap changer arms have completed one revolution and just prior to leaving the last contact, control disc (19) moves the change-over arm (20) to its other position. The drive is transferred to shaft (22) by means of a coupling shaft (21), which passes into the tap changer tank through a bearing housing (23). During a change of direction, the Geneva gear (18) remains stationary for one step due to the free gearing in the backlash coupling (16), allowing the reversing switch to operate first after the tap changer has left the last contact even with operations in the opposite direction.
LEGEND ITEMS FOR FIGURE 7A AND 7B
1) SHAFT COUPLING AND SHAFT
2) BEVEL GEAR (SMALL)
3) BEVEL GEAR (LARGE)
4) CAM SHAFT
5) GEAR DRIVE SUPPORT
6) SPRING OPERATOR CRANK
7) DRIVE PIN
8) SPRING BATTERY
9) FLY WHEEL
10) FLYWHEEL SHAFT
11) DISK BRAKE
12) GENEVA GEAR DRIVE
13) GENEVA GEAR
14) LTC SHAFT
15) DRIVE SUPPORT
16) BACKLASH COUPLING
17) GENEVA GEAR DIVE
18) GENEVA GEAR
19) CONTROL DISK
20) CHANGE-OVER ARM
21) COUPLING SHAFT
22) SHAFT
23) BEARING HOUSING
UZD® TANK - EXTERNAL

Weights and Dimensions

Dimensions in Figure 8 below show inches first with millimeters in parentheses. If only one number is given it is in millimeters.

UZD® weight without oil = 1,437 lbs (652 kgs)
BUE Motor Drive Mechanism weight = 260 lbs (118 kgs)
UZD® without oil + BUE weight total = 1,697 lbs (770 kgs)
UZD® holds 100 US gal liquid. Weight of 100 gal mineral oil = 750 lbs (341 kgs)
Total weight of UZD® + BUE + mineral oil = 2,447 lbs (1111 kgs)
Tank and Accessories

A number of flanges exist for a variety of accessories. Flanges that are not used are provided with a plate steel cover. See Figure 1, page 6 for the location and function of these flanges.

Flanges are typically raised with tapped holes or untapped holes for through bolts. Grooves for recessed O-ring gaskets are located either in the flange or in the device to be mounted on that flange. Standard accessories include a pressure control relay, a bottom drain valve with sampling port, and outlet and inlet ports plus internal plumbing for an externally mounted oil filtration system. The front door is hinged.

The UZD® tank is a welded, carbon plate steel enclosure and is supplied with a weld-able flange to facilitate mounting the UZD® tank to the transformer tank. The bottom of the oil-filled switching compartment is sloped toward the middle of the tank and also sloped toward the left side of the tank so that all oil flows to the drain valve.

The BUE drive mechanism is bolted to the bottom of the spring drive compartment after the tap changer tank has been welded to the transformer tank. The drive shaft and housing connecting the BUE to the spring drive compartment can be ordered in several lengths, to be specified by the transformer designer, so the BUE can be mounted at a convenient height above ground. A bracket on the bottom of the BUE is connected to the tank wall for stabilization if a drive shaft extension is used.

Two access panels accommodate entry into the spring drive mechanism compartment, both of which are fastened with bolts. Two vents provide ventilation. One vent is located in the bottom of the compartment near the front, and the other vent is located near the top at the back. The vents are fitted with sintered bronze filters to prevent insects from entering. Air heated in the BUE motor drive can rise up the drive shaft tube housing into the spring drive compartment. For ambient temperatures below −40°C, an extra heater can be provided in the spring drive compartment to prevent condensation.
The UZD® tank is designed to withstand full vacuum to 14.5 psi positive pressure. Vacuum can be pulled on the transformer tank with atmospheric pressure in the UZD® tank and vacuum can be pulled on the UZD® tank with atmospheric pressure in the transformer tank. Bypass piping between the two tanks is not required. Vacuum filling of the UZD® oil compartment is also not required.

The tank is not completely filled with oil. The gas space above the oil serves as expansion space for the oil. The UZD® has a vent hole in the top center of the tank. This should be connected to an Auto-Recharging Dehydrating Breather (ARDB), mounted at eye level, to assure the air entering the compartment is dry. A dehydrating breather must be used as high water content in the oil will lead to LTC failure.

A liquid level indicator is included with the UZD® with low level contacts. SPX Waukesha recommends that alarm contacts be connected to signal that the transformer should be taken off-line should the oil level reach the critical minimum level, thereby helping to prevent dielectric failures due to low oil level.

A pressure control relay is provided as standard and is designed to indicate excessive pressure in the tap changer switching compartment if a fault occurs and then send a signal to the transformer protective equipment to disconnect the transformer from the system if there is an unusually high pressure inside the UZD® tank. Under normal operating conditions, the switch will operate in less than 5ms. Contacts on this relay are factory set to close at 4.3 psi ±5%. Contacts from the sudden/rapid pressure rise relay can also be used to trip the transformer off-line in the event of a fault in the LTC.

The UZD®'s interior and exterior are painted with a two part epoxy primer. The interior and exterior of the spring drive and motor drive mechanisms are then top coated with a two part urethane paint in ANSI 70, sky grey. Upon request, the outside top coat process can be eliminated, so the transformer manufacturer can paint with desired paint formula and/or color.

Other standard accessories include the following:

- Bottom drain valve— One inch, flange mounted, globe valve with 3/8" sampling valve
- Upper vent hole — One inch with flange and cover
- Pressure switch — United Electric H100 series
- Magnetic liquid level gauge — Qualitrol, 6 inch 032 series with one form ‘C’ low alarm contact
- Flange for pressure relief device — 6 x 5/8 inch diameter holes on 9.25 inch diameter bolt circle
- Flange for Sudden Pressure Relay
- Opening for temperature probe
- Opening for thermal switch
- Mounting provision for heater in Spring Drive Mechanism

Optional Accessories:

- ARDB2 (Auto-Recharging Dehydrating Breather)
- OF2 Oil Filtration System
- Pressure relief device — Qualitrol series 208
  - Option: one form ‘C’ contact with ANSI style connector
  - Option: yellow plastic semaphore flag
- Sudden Pressure Relay —Qualitrol series 910 for gas space, flange mounted, ANSI style connector
- Thermal probe—Transformer manufacturer must provide gauge, RTD or end use of probe signal
- Thermal switch—Barksdale type MT1H set at –40°C for mineral oil
BUE MOTOR DRIVE MECHANISM

The BUE motor drive mechanism is designed for outdoor operation of the UZD® Load Tap Changer. Operating temperature range is –40°C (–40°F) to +50°C (122°F).

The BUE contains all of the equipment necessary to supply mechanical power to the UZD® and provide electrical signalling, protection and operation. The “90” voltage regulating relay, other associated control devices, and power supply circuit breaker are normally mounted in the main transformer control cabinet and wired to the BUE.

Cabinet

The BUE cabinet is made of welded sheet steel and treated for outdoor use. The BUE’s interior and exterior are painted with a two part, epoxy primer and then with an ANSI 70, sky grey, two part urethane top coat. Upon request, the outside top coat process can be eliminated, so the transformer manufacturer can paint with desired paint formula and/or color.

Referring to Figure 9, the front door is formed as a cap to allow access to all parts of the mechanism. The door can be hinged on either the left or right hand side and can be modified at any time. Provision is made for padlocking with a maximum 3/8 inch (10 mm) hasp. An inspection window on the front door permits viewing of the position indicator, maximum and minimum position drag hand indicators, tap change in progress flag and operations counter. The front door and inspection window are sealed with rubber gaskets.

A horizontal bracket should be provided by the transformer OEM for attaching the bottom of the BUE cabinet to the transformer tank wall (see Figure 8B for suggested bracket design) when a drive shaft extension is used. A two inch diameter phoenix flange welded in the back of the BUE allows for connection of conduit for electrical wiring from control box (see Figure 8C for dimensional location). This opening is plugged for shipment. Two sintered bronze filters provide ventilation while also preventing insects from entering. One vent is placed near the front in the bottom of the compartment and the other near the top at the back of the compartment. An interior cabinet light is provided and activated with a door switch. The drive shaft for connection to the UZD® is in the top of the BUE (see section above on UZD® tank description for more details).

There are two studs welded to the back of the BUE near the top. One stud has a double hose clamp for securing hoses going to the Oil Filtration System. The other stud has a single hose clamp for securing the hose for the ARDB (silica gel breather) typically mounted behind and below the BUE. There is a 2” x 3/4” two hole ground pad welded to the bottom of the BUE for external tank grounding.

Heater

There is a 200 w PTC (positive temperature coefficient) anti-condensation heater mounted in the BUE. This heater is always “on” and varies heat output based on ambient temperature; therefore, no thermostat is required. The heater has a fan which circulates the warmed air around the cabinet.

Gearing

Referring to Figure 10A, the motor (140) operates via a toothed belt (101) with a ratio of 5:1, turning operating shaft (105). This shaft (105) has a bevel gear (102) with a ratio of 5:1, and turns outgoing shaft (103). Hand crank (104) is applied to operating shaft (105). Twenty-five revolutions of the hand crank produces five revolutions of outgoing shaft which is required to complete one tap change operation. The maximum allowable torque on the outgoing shaft is 43.4 ft-lbs. The operating time is approximately 6 seconds with an 1150 rpm motor. When viewed from above, the outgoing shaft turns clockwise for a raise operation.

Motor

The standard motor supplied has the following ratings: single-phase, 115 volt, 60 Hz, 1150 rpm, 0.2 HP, with automatic reset thermal overload device to prevent over-heating. The motor is designed for intermittent duty.

See Figure 23, page 37, Contact Timing Diagram for information on when electrical contacts in the BUE open and close during the course of a tap changer operation.
FIGURE 9: BUE CABINET

Items are only used with the integrated style oil filter system and not provided when standard external Oil Filtration System (OF2) is used.
FIGURE 10A: MOTOR DRIVE MECHANISM – EXPLODED VIEW
LEGEND – ITEMS FOR FIGURES 10A AND 10B

101) TIMING BELT
102) BEVEL GEAR (LARGE)
103) COUPLING SHAFT
104) HAND CRANK
105) OPERATING SHAFT
106) SPUR GEAR (SMALL)
107) “ONE TURN” SHAFT
108) GENEVA GEAR DRIVE
109) BEVEL GEAR
110) MECH. POS. INDICATOR
111) COUPLING
113) MECHANICAL END STOP
114) BREAK-OFF SAFETY PIN
115) CAM DISK FOR (138)
116) ARM
117) BRAKE
118) BRAKE DISC
119) FRONT PLATE
120) OPERATION COUNTER
121) PULLEY (MOTOR)
122) PULLEY (GEAR)
123) BEVEL GEAR (SMALL)
124) SPUR GEAR (LARGE)
125) GENEVA GEAR
126) GENEVA GEAR
127) CONTACT DEVICE
128) CAM BAR
129) BRAKE FOR MAINTAINING CONTACT
130) CAM DISC FOR 137
131) DRIVING DISC FOR 130
136) COUNTER ARM
137) START CONTACTS (33S)
138) MAINTAINING, INTERLOCKING, AUXILIARY CONTACTS
139) LIMIT SWITCH (LS-1 AND LS-2)
140) MOTOR
141) INTERLOCK SWITCH
Hand Crank
Referencing Figure 10A, the mechanism can be manually operated by means of a hand crank (104) on the operating shaft (105). The direction of operation is shown on an instruction plate where the hand crank is inserted for manual operation. When the crank handle is inserted for manual operation, interlocking switch 84H (141) opens the circuit to the motor contactors, thus preventing electrical operation when the crank handle is inserted. A holder bracket for the crank handle is provided on the inside of the BUE's door.

One-turn Shaft
Referencing Figure 10A, power from the outgoing shaft drive is transferred by means of a cylindrical gear (106) with a ratio of 5:1 to a spur gear (124) on shaft (107). The shaft therefore rotates one turn for each tap change operation, indexing the Geneva gear (126) one position for each full revolution of the one-turn shaft per tap change. The driving pin on the Geneva gear drive (108) will be in the slot on the Geneva gear (125) in a normal operating position.

Position Indicator
Referencing Figure 10A, the Geneva gear (125) operates the mechanical position indicator (110) via a bevel gear (109). The position indicator includes two manually resettable drag hand indicators with a scale on the front plate (119), which is visible through the window in the door.

Electrical and Mechanical End Stops
Referencing Figure 10A, there are two screws mounted on Geneva gear (125) at the end of travel positions. As the Geneva gear rotates to an end position, one of the screws moves Rotary end stop (113) which actuates Limit switch LS-1 (139) for the raise direction or LS-2 (139) for the lower direction. This opens the circuit to the motor contactors and the two circuits of the motor supply. Electrical operation beyond the end positions is thus prevented.

In the case of faulty limit switches, the motor will be stopped by the mechanical end stop. A slot on the opposite end of rotary end stop (113) will cause the mechanical end stop to rotate so as to interfere with a bar cast into the top of bevel gear (102), preventing further motion in that direction. The break-off safety pin (114) on the manual operating shaft's conical toothed wheel (123) prevents over-loading of the end stops.

Contact Device
Referencing Figure 10A and 10C, shaft (107) is connected to the Geneva gear drive (112) via a coupling (111) and, with a ratio of 36:1, drives a Geneva gear (126) on the shaft of the contact device (127). The contact device moves 1/36 of a turn, or 10°, per tap change. The Geneva gear drive (112), with its driving pin, will rotate 180° in relation to the Geneva gear drive (108).

Continuation Contact (84C)
The contact device is also supplied with a continuation contact 84C when the tap changer has two or more positions with the same voltage (through-positions). One of these positions is the normal position. The through-positions are passed by automatically with electrical operation. See description of operation for more detail.

Maintaining Contact
Referencing Figure 10A, cam disc (115) on shaft (107) operates a roller on arm (116) operating the maintaining, interlocking and auxiliary contacts of device 33 (138). In the raise direction, the maintaining contact 33R closes the operating circuit for the motor contactor 84R. In the lower direction, the maintaining contact 33L closes the operating circuit for the motor contactor 84L.

Interlocking Contact
Referencing Figure 10A, contact 33-R1 (138) or 33-L1 (138) opens the operating circuit for the motor contactors. These contacts act as interlocking contacts if the motor rotation should be incorrect due to incorrect phase sequence.

Auxiliary Contact
Referencing Figure 10A, contacts 33E, 33F, 33G and 33H (137) are auxiliary contacts for providing a signal during a tap change operation.

Brake
Referencing Figure 10A, arm (116) operates a brake (117) through cam bar (128). The brake is applied to both sides of brake disc (118). The brake helps ensure the driving mechanism's outgoing shaft stops in the correct position after each tap change operation.
FIGURE 10C: MOTOR DRIVE MECHANISM - EXPLODED VIEW

103) COUPLING SHAFT
104) HAND CRANK
110) MECH. POS. INDICATOR
111) COUPLING
112) GENEVA GEAR DRIVE
115) CAM DISK FOR (138)
116) ARM
117) BRAKE
118) BRAKE DISC
119) FRONT PLATE
120) OPERATION COUNTER
122) PULLEY (GEAR)
125) GENEVA GEAR
126) GENEVA GEAR
127) CONTACT DEVICE
128) CAM BAR
129) BRAKE FOR MAINTAINING CONTACT
130) CAM DISC FOR 137
131) DRIVING DISC FOR 130
136) COUNTER ARM
137) START CONTACTS (33S)
138) MAINTAINING, INTERLOCKING, AUXILIARY CONTACTS
139) LIMIT SWITCH (LS-1 AND LS-2)
140) MOTOR

THROUGH SLOT

LEGEND – ITEMS FOR FIGURE 10C
**Indicator Flag**

Referencing Figure 10A, an indicator flag mounted on arm (116) is visible through a slot in the front plate (119). When the mechanism is on a valid tap position, the flag will be located beneath the area labelled “Position”. During a tap change, the flag is moved to “Raise” or “Lower”. Indicator flag and front plate are visible through the door window.

**Maintaining Contact Brake**

Referencing Figure 10A, a brake (129) with brake blocks constructed from Bakelite polymer is positioned on cam bar (128) outside brake (117). This maintaining contact brake prevents arm (116) from swinging over into the opposite direction when it swings back to its normal position at the end of a tap change operation thus preventing and additional unwanted tap change operation.

**Start Contact**

Referencing Figure 10A through 10C, start contact 33S-1(137) is operated by cam disc (130) which is freely suspended high up on shaft (107). The cam disc is driven by a pin in driving disc (131), which is fastened to shaft (107). 33S-3 (137) is an extra contact with the reverse contact function of 33S-1.

**Operation Counter**

Referencing Figure 10A, a six digit Operation counter (120) mounted behind the front plate (119) is driven by arm (136), registers the total number of tap change operations and is visible through the door's window.

**Controls**

Referencing Figure 9, page 21, Local-Remote and Raise-Off-Lower control switches are provided in the BUE. A UZD® equipped with an optional integrated oil filtration system also includes a filter ON-OFF reset switch and filter status indicating lights.

**Protection**

Referencing Figure 10C, the motor (140) has an automatic reset, thermal overload device to help prevent over-heating. The motor is designed for intermittent duty. Adjustable limit switches, LS-1 (139) for the maximum raise direction and LS-2 (139) for the maximum lower direction, are provided to block operation of the mechanism at end of travel. Mechanical end stops are also provided to prevent further movement of the mechanism should the end of travel limit switch fail to operate.

**Over-Current Blocking**

For automatically operated mechanisms, relay equipment provided by the transformer OEM shall include a 50-1 Overcurrent relay to prevent tap change operations from being initiated if the current exceeds 1200A (twice the rated current). If an over-current should occur once the operating sequence has begun, the over-current relay breaks the operating circuit and the driving mechanism stops.

If the current decreases, the over-current relay closes and the drive mechanism continues to the normal position. Note that the contacts of the load tap changer are in normal operating position and carry current as normal, even if the driving mechanism has stopped in an intermediate position because of over-current blocking.

**Indication**

Referencing Figure 10C, a mechanical position indicator (110) is provided as are manually resettable drag hands for indication of maximum and minimum operating positions. A “tap change in progress” indicating red flag (116) is also included along with an operations counter (120). These four devices are all viewable through the window in the door.
Wiring and Connections

Standard control wiring in the BUE is black, TEFZEL (ETFE) insulation, AWG 12 wire size and rated to 150°C. Wire designation is accomplished with heat shrink wiring sleeves. Terminal blocks for wiring connection are DIN rail mounted, Idec type BHN30W, rated for 30 amperes. Wires are terminated at terminal blocks with crimped-on ring tongue terminals.

Optional Accessories

Several options are available in the BUE motor drive mechanism, including

- Resistance Position Transmitter that closes a contact to add/subtract a discrete resistor from the circuit
- Resistance Position Transmitter that is a potentiometer
- Selsyn Position Transmitter
- Incon Position Transmitter
- Dynamic Ratings Position Transmitter
- Incomplete step alarm contact
- Odd/even tap position contact
- Contacts for step-by-step operation
Operating Principles

LOAD TAP CHANGER

Switching Sequence
The switching sequence is designated as the symmetrical flag cycle, meaning that the main switching contact of the selector switch “S” (Figures 11-18) breaks after one resistor is positioned in the circuit but before both resistors are positioned in the circuit so that the circulating current has not yet started to flow. This ensures maximum reliability when the switch operates with overloads.

With the transformer carrying load, the breaking takes place at the first current zero after contact separation, equating to an average arcing time of approximately 5–6 milliseconds at 60 Hz. The total time for a complete sequence of movement of the selector switch after the spring battery discharges is approximately 70 milliseconds. The time for the motor drive mechanism to wind up the spring battery in the spring drive mechanism to the point of discharge and get to position for the next tap change operation is approximately 6 seconds.

Arcing Tap Switch (Tap Selector Switch)
The switching sequence, when switching from stationary contact position D1 to stationary contact position D2, is shown in the series of Figures 11–18.

FIGURE 11
LEGEND – CONTACTS FOR FIGURE 11
R) TRANSITION RESISTOR (R1 AND R2)
D) STATIONARY CONTACT (D1 TO D18)
H1 / H2) TRANSITION ARCING ROLLER CONTACT
I) MOVING MAIN CURRENT CARRYING CONTACT
S) MOVING MAIN SWITCHING ARCING ROLLER CONTACT
C) COMMUTATOR HUB
→ CURRENT FLOW

FIGURE 12
Starting at rest on stationary contact D1, the main current carrying contact I carries the load current to the commutator hub. The transition arcing roller contacts H1 and H2 are open, resting in the spaces between the fixed contacts. No current is flowing through the transition resistors R1 or R2.
Transition arcing roller contact H1 makes with stationary contact D1. Transition resistor R1 is now carrying a small amount of current but most of the through current is still flowing through moving main current carrying contact I.

Main current carrying contact I breaks with stationary contact D1. The moving main switching arcing roller contact S breaks with stationary contact D1. At this point, all through current is carried by transition arcing roller contact H1 and transition resistor R1.

Transition arcing roller contact H2 makes with stationary contact D2. The through current is split between the transition contacts H1 and H2. The circulating current is now established and is driven by the step voltage between contacts D1 and D2 and limited by transition resistors R1 and R2 in series to the circulating current. The circulating current could be adding to or subtracting from the through current.
Transition arcing roller contact H1 breaks from stationary contact D1. At this point, all through current is carried by transition arcing roller contact H2 through transition resistor R2. The circulating current path is broken.

Moving main arcing roller switching contact S makes with stationary contact D2 and carries the through current. The moving main current carrying contact makes with stationary contact D2 and carries the through current, while a small portion of the current is carried by transition resistor arcing roller contact H2 through transition resistor R2.

Transition arcing roller contact H2 breaks with stationary contact D2. Main current carrying contact I is now carrying all the through current. The tap change is complete and the selector switch is at rest on stationary contact D2.
Reversing Change-Over Selector for Plus/Minus Switching (Figures 19A, B and C, page 32)

This device also called a reversing switch, is used to change the polarity of the regulating winding 180° with respect to the winding being regulated. This allows double duty of the contacts on the selector switch, i.e. each stationary contact can be used twice, once in the raise direction and again in the lower direction.

When a raise command is received with the selector switch in 1L (contact number 16 on phase molding), the selector switch moves to LN, or lower neutral (contact 17 on phase molding, a through position) and then continues on to N, or neutral (contact 18 on phase molding). The contact arm of the selector switch makes two tap change operations on either side of neutral without stopping (through positions). This operation is programmed into the BUE Motor Drive Mechanism via continuation contact 84C (see contact timing diagram below).

At N/neutral, moving contact R carries no current. The two stationary reversing switch contacts are connected to the adjacent selector switch contacts, 1 and 17, by copper rods internal to the epoxy phase molding. The load current travels from the main winding being regulated, through N (contact number 18 on phase molding) and out through the selector arm's center contact (19 or 0 on the phase molding). The regulating winding's top end remains connected to the main winding. The tap changer stays in this position until another raise or lower command is received.

If a lower command is received, the selector switch will reverse the above movements. However, if a raise command is received, moving contact arm R travels from contact 17 to contact 1 while the spring battery is being charged to move the selector switch from N/neutral (contact number 18 on phase molding) to RN/raise neutral (contact number 1 on phase molding). This turns the winding direction, or polarity, of the regulating winding 180° with respect to the main winding being regulated. Continuation contact 84C remains closed and initiates a second tap change operation which moves the selector switch from RN to 1R position (contact number 2 on phase molding).

Through-Positions

Contact positions LN and RN mentioned above are termed 'through-positions' since the tap changer is programmed to automatically step through these locations. If the tap changer is set up to use less than 33 positions, some of the selector switch's fixed contacts are connected to the same tap of the regulating winding. Therefore, several more through-positions occur. When the motor drive mechanism is initiated electrically (as opposed to manual hand cranking), it will automatically pass those ‘through-positions’ and stop in the ‘normal position’.
FIGURE 19A: SWITCHING SEQUENCE — STAGE 1
Wiping action on a stationary contact where the moving contact is "on".

FIGURE 19B: SWITCHING SEQUENCE — STAGE 2
Moving contact switches from one stationary contact to other stationary contact.

FIGURE 19C: SWITCHING SEQUENCE — STAGE 3
Moving contact wipes the stationary contact to final position.
The motor drive mechanism provides the motive force that makes
the tap changer operate. The force is provided by a motor through
a series of gears and on to a drive shaft to transmit the energy to
the spring drive mechanism. Several features are incorporated to
promote long service intervals and reliability.

The basic tap changer control circuit consists of a Local-Remote
selector switch (43T-2), a Manual-Automatic selector switch
(43T-3), a Lower-Off-Raise selector switch (43T-1), a voltage
regulating relay with output contacts for raising and lowering the
load tap changer (90R and 90L), an over current relay (50-1),
motor contactors (84R and 84L), limit switches (LS-1 and LS-2)
and interlocks. Figure 21 shows these features on a typical Control
Schematic. The voltage regulating relay (90) and the over current
relay (50-1) are provided by the transformer OEM in the transformer
control cabinet.

NOTE: Some older phase moldings may not have any terminal numbers next to terminals.
Newer moldings may show a "0" (zero) for the terminal shown as 19 on the
Connection Diagram. Terminal 0 and 19 are the same. If the phase molding does
not have a terminal 19 as shown in the Connection Diagram, make connection to
the terminal marked 0 on the phase molding.
Timer T-1 and connected devices are included for optional integrated oil filtration system. These items are located in external OF2 oil filter as standard.
DRIVE MECHANISM

DEVICE NO. DESCRIPTION

33 MAINTAINING CONTACT
33S STARTING CONTACT
33SPT SYNCHRO POSITION TRANSMITTER
43T-1 LTC LOWER-OFF-RAISE SWITCH
84C/33N CONTINUATION CONTACT W/CLOSED NEUTRAL
84H HAND CRANK LOCKOUT SWITCH
84L MOTOR CONTACTOR, LOWER
C1 CAPACITOR
CO-2 CONVENIENCE OUTLET
125V, 20A
H-3 HEATER ASSEMBLY
200W, 120VAC
HS-2 HEATER SWITCH, OFF-ON
2 POS., 1NO – 1NC
LS LIMIT SWITCH
LT-3 CABINET LIGHT
LTS-2 DOOR OPERATED LIGHT SWITCH

FIGURE 22: CONTROL SCHEMATIC – DEVICE LEGENDS

<table>
<thead>
<tr>
<th>CONTACTS</th>
<th>POSITION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>OFF</td>
<td>X</td>
</tr>
<tr>
<td>3-4</td>
<td>ON</td>
<td>X</td>
</tr>
</tbody>
</table>

X - CLOSED CONTACT

43T-1 (SPRING RETURN TO CENTER)

<table>
<thead>
<tr>
<th>CONTACTS</th>
<th>POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>LOWER</td>
</tr>
<tr>
<td>3-4</td>
<td>RAISE</td>
</tr>
</tbody>
</table>

X - CLOSED CONTACT
Contact Timing Diagram
The raise and lower operation diagrams illustrate contact operating sequences for one tap change operation equal to 25 turns of the hand crank shown across the top of the diagram. The lower three diagrams demonstrate the contact sequence for the electrical limit switches and the continuation contact for the through-positions.

Local Control
The mechanism can be operated by control switch 43T-1 “Lower-Off-Raise”. To operate the tap changer manually, 43T-2 should be in the “Local” position, and 43T-3 should be in the “Manual” position.

SEQUENCE OF EVENTS FOR A RAISE OPERATION IS AS FOLLOWS:
When the 43T-1 Lower-Off-Raise switch is operated in the Raise position, raise relay 84R becomes energized. The contactor closes and is held by start contact 33S-1 and its own holding contact. The raise relay 84R interlocks with a normally closed contact of the lower contactor 84L, a limit switch LS-1 that opens at the maximum tap changer operating position 16R and an interlock switch 33L-1 which opens when the operating shaft rotates in the direction that produces a decrease in the tap changer operating position.

The motor starts and drives the mechanism in the raise direction. Maintaining contact 33L closes and holds contactor 84L. At the same time, the mechanical brake (117, Figure 10A) is released. Then start contact 33S-1 opens. Contact 33L is closed until just before the tap change is completed, then it breaks, the contact is released, the motor is disconnected and the brake begins to operate. Start contact 33S-1 closes again. The brake stops the driving mechanism and the tap change is complete.

Remote Control
To operate the tap changer by remote control, control selector switch 43T-2 must be in the “Remote” position. A terminal in the motor drive cabinet supplies control voltage for the remote push buttons. Incoming control circuits for raise and lower impulses connect to other terminals as shown in the schematic diagram Figure 21, page 34. Local operation is not possible when switch 43T-2 is in the “Remote” position, and remote operation is not possible when in the “Local” position.

Automatic Operation Local Mode
To operate the tap changer automatically, 43T-2 must be in the “Local” position and 43T-3 in the “Automatic” position. The tap changer can now be operated by the “90” voltage regulating relay. The “90” relay compares the 120 volt signal from a potential transformer on the bus to be regulated, to the adjustable “set value” reference voltage in the “90” relay to determine if a tap change is required and, if so, in which direction. The bus voltage signal must be outside the adjustable “bandwidth” setting of the “90” relay and for a length of time longer than the adjustable “time delay” setting of the “90” relay for a tap change operation to be initiated. If voltage drops below the lower voltage limit and remains below the lower limit for the duration of the time delay setting, a raise tap change operation will be initiated by energizing the raise output relay 90R. This initiation operation also energizes the raise relay 84R. The raise output relay remains energized until the tap changer operation raises the voltage to a value above the lower limit of the bandwidth which is then maintained to assure a complete operating cycle as described earlier for manual operation.

Similarly, if the bus voltage is too high, the above process repeats but in the lower direction.
**Over-current Relay**

An over current relay “50-1” shall be provided in the seal-in circuit to prevent the tap changer from operating when the load current is excessive such as during a short circuit. The 50-1 is adjustable from one to two times full load current.

**Through-Positions**

The UZD® load tap changer operates automatically in two positions: one labelled raise neutral/RN and the other labelled lower neutral/LN. Each of these positions includes a connection that produces the same voltage as neutral. A continuation contact 84C is closed when the tap changer is in one of these two positions, as can be seen in the Contact Timing diagram Figure 23. This closure causes the mechanism to make an additional tap change operation to prepare for the reversing change-over selector to operate without current flow.

When operating over a through-position in the raise direction, maintaining contact 33R is bridged by continuation contact 84C via a contact on motor contactor 84R (raise). Contactor 84R remains energized, causing the mechanism to automatically carry out a second raise operation.

When operating over a through-position in the lower direction, maintaining contact 33L is bridged by continuation contact 84C via a contact on motor contactor 84R. Motor contactor 84L (lower) remains energized and the mechanism automatically carries out a second lower operation.

If the motor power supply opens and then recloses in a through-position, only the motor contactor 84L will be energized. The mechanism then moves in the lower direction to a normal position.

With manual hand crank operation, the mechanism must be put into a ‘normal’ position. If the mechanism is left between two positions or in a through-position, the mechanism starts immediately upon removal of the hand crank.

**Step-by-Step Operation**

Step-by-step operation is an optional feature only used in the manual mode. The UZD® will make tap change operations continually if the raise or lower switch is held. In step-by-step operation, only one tap change will be made until the raise or lower switch has been released. When the raise or lower switch is operated again, one more tap change will occur. Upon request, a relay 84S will be provided in the BUE cabinet to perform this function.
Technical Data and Characteristics
RATINGS – INSULATION LEVEL

TABLE 1: ELECTRICAL RATINGS

<table>
<thead>
<tr>
<th></th>
<th>TAP CHANGER DESIGNATION</th>
<th>UZDRT 200/600</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>MAXIMUM RATED THROUGH CURRENT</td>
<td>600 AMPS</td>
</tr>
<tr>
<td>3</td>
<td>RELEVANT RATED STEP VOLTAGE AT MAXIMUM RATED THROUGH CURRENT OF 600 AMPS</td>
<td>600 VOLTS</td>
</tr>
<tr>
<td>4</td>
<td>MAXIMUM STEP VOLTAGE AT RATED THROUGH CURRENT OF 200 AMPS</td>
<td>1200 VOLTS</td>
</tr>
<tr>
<td>5</td>
<td>SHORT CIRCUIT WITHSTAND CAPABILITY (PEAK /RMS) 2 SECONDS</td>
<td>30 kA/12kA</td>
</tr>
<tr>
<td>6</td>
<td>NOMINAL SYSTEM OPERATING VOLTAGE</td>
<td>34.5 kV</td>
</tr>
<tr>
<td>7</td>
<td>HIGHEST OPERATING SYSTEM VOLTAGE</td>
<td>34.5 kV</td>
</tr>
<tr>
<td>8</td>
<td>INSULATION BETWEEN ALL LIVE PARTS TO GROUND AND BETWEEN PHASES, FOR CONTINUOUS VOLTAGE OPERATION</td>
<td>34.5 kV</td>
</tr>
<tr>
<td>9</td>
<td>DIELECTRIC WITHSTAND IMPULSE OF 1.2 X 50 MICROSECONDS NEGATIVE AND POSITIVE POLARITY AND AC (1 MINUTE FOR 60 HZ)</td>
<td>IMPULSE KV PEAK AC KV</td>
</tr>
<tr>
<td></td>
<td>Live Parts to Ground</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Between Adjacent Phases</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Between First and Last Contacts</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Between Adjacent Contacts</td>
<td>60</td>
</tr>
</tbody>
</table>

| 10 | MAXIMUM NUMBER OF SERVICE TAP POSITIONS | 33 |
| 11 | MAXIMUM NUMBER OF INHERENT TAP POSITIONS | 35 |
| 12 | REGULATING SCHEME | REVERSING (PLUS-MINUS) |
| 13 | NUMBER OF TAPS IN THE REGULATING WINDING | 16 |
| 14 | MAXIMUM SERVICE VOLTAGE ACROSS REGULATING WINDING | 10 kV at 600A 20kV at 200A |
**TRANSITION TIME**

The BUE motor drive mechanism needs approximately six seconds to complete 25 revolutions of its output drive shaft to make one tap change operation. The output drive shaft from the BUE stores energy by tensioning springs in the spring drive mechanism. Once the spring operator crank passes top dead center and the springs discharge, the selector switch takes approximately 70 milliseconds to complete one tap change operation. Arcing time of approximately six milliseconds occurs during the 70 millisecond selector switch transition time.

**STANDARDS AND TESTING**

Design tests were performed and passed to verify the UZD®'s ability to meet the specified requirements in IEEE C57.131-1995 and IEC 60214. Copies of design test reports are available upon request.

**RATING PLATE**

Design tests included the following:

- Temperature rise of contacts
- Switching
- Short-circuit current
- Transition impedance
- Mechanical
- Dielectric

Routine tests performed on each UZD® tap changer include:

- Proper assembly verification
- Mechanical test
- Auxiliary circuits insulation test
- Final inspection
STEP VOLTAGE AND THROUGH-CURRENT

The maximum allowable step voltage is limited by the electrical strength and switching capacity of the selector switch and is, therefore, a function of the rated through-current as shown in Figure 27 (step voltage/y axis vs. rated through-current/x axis) below. The rated through-current of the tap changer is the continuous current which the tap changer is capable of transferring from one tap to the next at the relevant rated step voltage.

The rated through-current and step voltage are used to select the transition resistor value in order to minimize arcing and maximize contact life. The rated through-current adjusted by the turns ratio of the series transformer (if applicable) helps determine the contact life.

MECHANICAL LIFE

SPX Waukesha’s UZD® load tap changer was tested to over a million operations based on Mechanical Endurance Test requirements. No mechanical failure occurred during testing nor did the components wear in ways which prevented the tap changer from functioning at the end of the test.

CONTACT LIFE

Predicted contact life of the selector switches’ fixed and moving contacts is shown in Figure 28. The UZD contact life curve shown assumes that all tap change operations are made at the maximum rating; however, transformers are rarely loaded to maximum rating.

Estimated contact life can be calculated by dividing the estimated contact life at maximum rating by an assumed load factor. In Table 2, the middle column assumes an average load on a transformer of 80% of the maximum nameplate rating. The right hand column assumes a 67% average load factor. Electrical contact life should never be assumed higher than 500,000 operations, although higher contact life may be possible.

To determine the interval between inspections, divide the estimated contact life by five.
REVERSE POWER FLOW
The UZD® operates on a symmetrical flag cycle, and, as such, arcing is the same for either current direction; therefore, reverse power flow should have no adverse effect on the UZD®. However, operating in reverse power flow mode is typically considered undesirable for step-down transformers as a voltage signal input to the regulating relay is not usually present from the HV bus and is a requirement for this to work properly. In most of these cases, therefore, the regulating relays sense reverse power flow and block operation of the LTC.

SHORT CIRCUIT STRENGTH
Tests conducted on the UZD® verify its ability to withstand 12,000 Amps for an equivalent two second time with a 30,000 Amps peak asymmetrical offset at the beginning of the test. These values are 20 times rated current, twice the amount required by IEEE C57.131-1995.

LOADING BEYOND NAMEPLATE
If the maximum rated current of the regulating winding is less than the rated through-current of the UZD®, the UZD® will not restrict occasional operation beyond nameplate rating of the transformer, in accordance with IEEE C57.91, CAN/CSA-C88-M90 and IEC 60354 as noted below:

While carrying 1.2 times maximum rated through-current continuously, tests shall be performed to verify that the steady-state temperature rise of the contacts does not exceed 20°C above the temperature of the insulating fluid surrounding the contacts.
- IEEE C57.131-1995, Paragraph 6.1.1: LTCs that comply with the above definition of maximum rated through-current, and when installed and properly applied in a transformer or regulating transformer, can be loaded in accordance with the applicable ANSI or IEEE loading guide. Per IEEE C57.131-1995, Paragraph 6.1.2

Tests conducted on a Waukesha® UZD® verify that all contact temperature rises meet the above requirements. Additional tests were conducted at 1.5 and 2.0 times maximum rated through-current to further verify the UZD®’s ability to carry currents which might occur if a transformer were loaded beyond nameplate rating per ANSI/IEEE C57.91.

MINERAL OIL/FR3 FLUID OPERATING TEMPERATURES
Tests conducted verify that the UZD® will operate in mineral oil at –25°C with no noticeable change in timing, will operate at –40°C with an acceptable 25% increase in timing, and may be operated at –50°C in a de-energized mode. Switching overload currents when the mineral oil is between –25°C to –40°C is not recommended.

Additional tests verify that the UZD® will operate in FR3 fluid at –15°C with no noticeable change in timing. A thermo-switch can be mounted in the bottom of the UZD® oil-filled compartment and connected to disable the motor drive circuit and prevent operation of the tap changer should the FR3 fluid temperature drop below –10°C. A heater circuit is in development to prevent the FR3 fluid from going below –10°C even after the FR3 fluid has cooled to temperatures as low as –40°C. If the UZD® will be filled with natural ester fluid, SPX Waukesha recommends that a Nitrogen Generator be used to bleed a small amount of nitrogen across the gas space in the UZD® to 1) sweep away arcing gasses generated, and 2) exclude oxygen and water vapor from entering the UZD® gas space. Contact SPX Waukesha for further information about this arrangement.

Operation at fluid temperatures up to +80°C is permitted in either mineral oil or FR3 fluid.

TIE-IN RESISTORS
During switching of the change-over selector switch, the regulating winding will be disconnected from the main winding and capacitively charged from the adjacent winding. If this voltage gets too high, the change-over selector switch contacts cannot break the capacitive current, whereby the regulating winding is short-circuited causing possible damage to the transformer.

Recovery voltage should be calculated and limited to a maximum of 20 kV if through current is limited to 200A or less or a maximum of 10kV if through current is greater than 200A. See Figure 27: Step Voltage vs. Rated Through-Current. The usual method to limit recovery voltage is by means of a high-resistance, tie-in (sometimes called a “damping”) resistor. The tie-in resistor is continuously connected between the midpoint of the regulating winding and the main winding. Values for this resistor typically range from 50 kΩ.
to 500 kΩ. As this resistor remains continuously in the circuit, the losses from this resistor should be reported in the no-load losses of the transformer. These high voltages are typically found in windings above 100 kV line-to-line for the terminal being regulated with a UZD®. All autotransformers should be checked for high recovery voltage.

Contact your SPX Waukesha channel partner if you need assistance with this calculation.

**SOUND LEVEL**

During the six seconds that the BUE motor drive is operating during a tap change, the sound level at one foot from the UZD®/BUE is an average 68 db(a) with a 0.4 second spike to 85 db(a) when the spring battery discharges. At five feet from the UZD®/BUE the sound level is 60 db(a) with a 0.4 second, 75 db(a) spike. While not making a tap change, there should be essentially no sound generated by the device.

**OPERATION AT LOWER AND HIGHER AMBIENT AIR TEMPERATURE**

The BUE motor drive mechanism will operate in ambient air temperatures from –50°C to +60°C. The compartment is heated with a Positive Temperature Coefficient (PTC) heater rated 200w. This positive temperature heater changes resistance with air temperature so its resistance goes up as the air temperature goes up and less current is passed, generating less heat. The reverse is true for lower temperatures. No thermostat is required as the heater is always on with varying output in relation to required heat.

The standard heater in the BUE is rated at 200w and is suitable for ambient air temperatures down to –25°C. Where it is expected to have ambient temperatures below –25°C then the optional 200w/400w heater should be specified. With this heater, the BUE can operate down to temperatures of –50°C. Shielding the BUE motor drive compartment from direct sunlight is required when ambient air temperatures are above +60°C.

**CONDUCTORS FROM WINDINGS**

The temperature of the conductors connected to the terminals on the back of the UZD® in the main transformer tank must not exceed 30°C over the surrounding oil temperature. Conductors must be appropriately sized to limit the temperature.

**GROUNDING**

If the UZD® is to be grounded, a cable lug described below should be connected to terminal 17 on the transformer side of the UZD® and connected via cable to a ground point somewhere in the transformer tank. A convenient place for these grounds would be on a stud welded to the tank wall in the area of the tank opening to accept the UZD®. There will be one cable per phase.

**CABLE LUGS**

Special cable lugs are connected to the stranded copper conductors coming from the windings. The cables must be crimp connected to these cable lugs. SPX Waukesha will provide the correct number of required lugs. Cables must be one of the following sizes and specified with UZD® order:

**TABLE 3: AVAILABLE CABLE LUG SIZES**

<table>
<thead>
<tr>
<th>CABLE AREA (mm²)</th>
<th>AWG</th>
<th>HOLE DIAMETER (mm)</th>
<th>SEE FIGURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1</td>
<td>11</td>
<td>29</td>
</tr>
<tr>
<td>95</td>
<td>4/0</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>150</td>
<td>300MCM</td>
<td>19</td>
<td>31</td>
</tr>
</tbody>
</table>

**FIGURE 29:** SMALL CABLE LUG, 1 AWG  
**FIGURE 30:** MEDIUM CABLE LUG, 4/0 AWG  
**FIGURE 31:** LARGE CABLE LUG, 300 MCM
Assembly to Transformer & Commissioning

RECEIVING INSPECTION

Unpacking
Upon receipt of a UZD®, inspect the packaging for signs of damage. For domestic shipments, remove the wooden cover protecting the contacts on the back of the UZD® and also the wooden cover protecting the pressure switch on the end of the UZD®. Remove banding, plastic and cardboard protectors from the BUE. For international shipments open the cover of the transport box and remove all shipping materials. UZD® and BUE can be left on the skid until mounted to the transformer.

The UZD® oil compartment is purged with dry nitrogen at 5 psi prior to shipment. This pressure should be relieved prior to attempting to open the oil compartment at any opening. Lift the handle on the small brass pop off pressure relief valve on the cover of the UZD® to relieve this pressure.

Product Verification
Confirm that the serial number, description and quantity match the shipping documents, including the packing list and order acknowledgement. The serial number can be found on the nameplate on the outside of the device.

Damage Inspection
Inspect the UZD® and BUE for visible signs of damage that may have occurred during shipment due to rough handling, including a search inside the BUE. If shipping damage is found that could cause the tap changer to function improperly, a damage report should be completed and sent to the freight carrier, freight forwarder and/or your insurance company. Photographs should be taken of the damaged areas, marked with the serial number of the tap changer and sent to SPX Waukesha for analysis and comment. Contact your SPX Waukesha Channel Partner for further discussion and disposition of any issues.

Moisture Evaluation
If the packing material seems wet (i.e. plastic is coated with moisture), the tap changer must be dried out before being mounted to the transformer. This can be accomplished in most cases by blowing hot air on the device (air temperature should not exceed 90°C). Applying pressure or vacuum is not necessary at this time.

See below for instructions if tap changer will not be installed immediately upon receipt.

Temporary Storage Before Assembly
If the UZD® will not be installed upon receipt, perform the receiving inspection as outlined above, verify the tap changer is approved for use and then store it in a warm, dry location until ready for assembly.

The tap changer oil compartment is filled with dry nitrogen under 5 psi positive pressure prior to shipping. If this valve is operated manually and there is no pressure, refill with dry air or dry nitrogen and perform a leak test. If the tap changer is opened and the nitrogen fill is lost and the UZD® will not be installed on a transformer immediately, the tap changer oil compartment must be purged and filled with dry nitrogen at a pressure not exceeding 5 psi before being stored in a heated building/enclosure.

The UZD® and BUE are not packaged for storage outdoors or in an unheated building. To store in these conditions, the following steps should be taken:
1) Fill and seal the UZD® with dry nitrogen at maximum 5 psi
2) Provide weather protection for the exterior of the tank and terminal boards (particularly the bare steel weld flange)
3) Energize built-in space heaters in the BUE
PREPARATION

To properly align the tap changer on the tank for welding, use the following procedure:

- Locate fit-up hooks on tap changer tank frame (“H” frame) — see Figure 32.
- Position the tap changer “lip” on hooks.
- Check level of spring drive bottom plate.
- Shim on hooks to improve level condition. Shims should be less than the depth of the notch in the fit-up hook.
- Tack weld tap changer tightly to tank frame.
- Tap changer attaching lip must be tack welded tight against frame before finish welding.

WELDING

(Figure 33) All welding should be done with G.M.A.W. (Mig) using .045” ER70S-6 wire and 95% Argon - 5% oxygen shielding gas at approximately 250 amps and 25 volts. If welding will be done in an area where smoke and contamination are not an issue, then 70 tensile flux core wire can be used. Overhead and horizontal welding shall be done with a straight, uninterrupted stringer bead. The arc should be directed into the joint at an angle of approximately 45°.

Vertical welding with G.M.A.W. (Mig) shall be completed in an upward progression using a pulsed arc method. The arc should be directed into the joint at an angle slightly less than 90°. Start the arc, and stop after a small shelf is established. Move the gun up approximately 3 mm, then start the arc again and maintain the arc long enough to obtain penetration into the joint. Stop the arc and move up another 3mm. Restart the arc again before the molten metal is completely cooled. Arc time should be long enough to obtain penetration but stopped before the molten pool drops. The vertical joints can be effectively welded in one pass regardless of the varying degree of joint gap.
Attach the UZD® tank assembly to transformer per the procedure described above. The BUE can be mounted directly under the UZD® Figure 34 or mounted lower than the UZD® with the use of an off-set mount (longer drive shaft and drive shaft enclosure) per Figure 35. These off-set shaft extensions are available in 60 mm, 500 mm, 1,000 mm and 1,500 mm lengths. If it is desired to rotate the BUE 90° with respect to the UZD®, an off-set shaft extension is required.
The UZD® and BUE are assembled at the factory so that both are in the same tap position. It they get out of sync (on different tap positions) damage will occur at some point of operation. Before disassembly, shipping “locks” are installed. There is one lock on the input shaft in the spring drive mechanism, see Figure 36, and one in the BUE where the hand crank is installed for manual operation, see Figure 37. It is critical that both devices be in the same position when they are assembled on a transformer. Both the UZD® and the BUE are in the neutral position when the locks are applied. The BUE can be assembled to the UZD® and then the locks can be removed. This will insure that neither device gets out of position during assembly.

Should the locks be removed prior to assembly, there are six things to check to verify that both UZD® and BUE are in the proper position prior to attempted operation. First, in the BUE motor drive, check that neutral position is indicated on the mechanical index position dial (position indicator). The black hand should be pointing straight up to position N. Second, verify that the red position indicator flag (located immediately above the mechanical position indicator) is in the middle of the slot indicating BUE is on position. See Figure 37 to the right.
Third, the red line on the disc brake wheel should be in line with the red line on the brake shoe. These lines are located in the upper left hand corner of the BUE directly in between and behind the springs mounted on the disc brake as shown in Figure 38.

Looking down on the top of the BUE, Figure 39 below shows these lines before the BUE is assembled into it’s cabinet.

Forth, in the spring drive mechanism compartment, the large bevel gear driven by the small bevel gear in line with the drive shaft from the BUE, should be aligned so that the bar molded into the back of the large bevel gear is pointing to a hole drilled into the support casting as shown in Figure 40.

Fifth, in Figure 36 there is a split pin shown protruding through the lower left corner of the red shipping lock. This pin connects the small level gear to the drive shaft from the BUE. The solid end of the split pin should be towards you when facing the red shipping lock. If the split end of this pin is facing out where the shipping lock was, the spring drive mechanism is 180º out of position and damage will occur when UZD® is operated at the tap extremes. It is possible to assemble these parts with the drive shaft 180º out of position so be sure this is in the correct position.
Figure 41 shows the position of the drive arm connected to the reversing switch Geneva wheel as it would appear if neutral is approached from a Raise position. This position indicates that the reversing switch in the oil compartment is on the back tap. The reversing switch can be on either tap for assembly and adjusts itself during operation.

In the oil compartment the reversing switch would be on the rear contact. After assembly the reversing switch is normally left on the front contact. It does not matter which stationary contact the reversing switch is on for assembly. Figure 42 below shows the reversing switch on the front contact.

Sixth, to verify neutral position in the oil compartment, the selector (dial) switch should be pointing straight up in the 12:00 o’clock position. See Figure 42.

Once it is known that all parts are in the proper position, attach extension tube to the top of the BUE cabinet and install gasket. Install the drive shaft through the extension tube and into the motor drive coupling. Place gasket on top of extension.

**Strap BUE to base on HY-BOY lift before attempting to lift BUE into place.**

Lift the BUE assembly (use Hy-Boy Lift) up to UZD® tank. Guide the drive shaft through opening in the UZD® tank so it can be lined up and inserted in the spring drive coupling.

Fasten extension tube to the UZD® tank. Secure the hardware with Loctite 271 Threadlocker. Use one to two drops of Loctite to properly secure hardware.

**Use of neoprene, butyl or natural rubber gloves is required to prevent skin contact with Loctite 271 Threadlocker.**
After installing the shaft, verify that the drive shaft has approximately 2–3 mm of end play and that the keys are positioned in the slots as shown in Figure 43 below. If end play is greater than 2–3 mm AND/OR the keys are not properly positioned in the slots, shim by placing up to four (4) cone washers on the bottom of the motor drive coupling and/or by placing up to two (2) cone washers at the top of the motor drive coupling. Now the 2 shipping locks can be removed.
LEAD CONNECTIONS

Tools
1) 30 ft-lb Torque Wrench
2) 3/8" Ratchet
3) 5/16" Allen Head Socket
4) Snips/Side Cutters
5) Drift
6) Adjustable Wrench
7) Hammer (Ground Straps)
8) Prick Punch (Ground Straps)

Materials
Loctite 27131 – Threadlocker

Procedures
1) Before lowering the core and coil assembly into the tank, crimp the cable lugs onto the cables coming from the regulating winding. Crimps shall be made on either side of the terminal, not top or bottom, and consistently placed on the same side on a given unit.

2) Do not taper the insulation at the end of the cable. After coil dryout (vapor phase) the gap between the end of the cable lug and the start of the insulation should not exceed 6 mm. Also the end of the insulation on the cable should be secured so it does not unravel.

3) Label each lead, indicating the position on the back of the phase molding to which it should be attached see Figure 45. Retrieve hardware for connecting leads qty 57 - M10 x 25 black oxide SHCS bellville lock washers and bolts.

Leads should be moved aside to accommodate connection of each lead to the LTC. Loosening clamps/cables on top of the internal assembly (top rack) may be necessary to reach these connections.

FIGURE 44 - LTC LEADS BEFORE CONNECTIONS

When making lead connections, begin with the bottom connections on A phase (left side) and work up. Next, secure the leads to the LTC on C phase (right side), again working from bottom to top. Finally, complete the connections to B phase (center), starting at the bottom and finishing at the top.

Each set of leads (19 leads for each phase) should be labeled to match with the individual locations on the LTC. Verify that the correct lead is connected to the correct location on the LTC. A turns ratio test should be performed before the cover is secured to the transformer.

FIGURE 45 - LTC LABELING
When securing leads to the LTC, no copper lead terminal can touch another copper lead terminal. These terminals must be installed parallel to each other, with a minimum of 6 mm between terminals. See Figure 46 & 47.

NOTE: On B phase, the LTC leads will cross over one another – connections on the left side of B phase will have the leads coming from the right, and connections on the right side of B phase will have the leads coming from the left.

NOTE: After securing the leads to the LTC with a ratchet, two operators are required to verify that each lead is properly torqued to 30 ft-lbs and in its correct location. One operator performs the actual check of each lead in the tank, calling out each lead as it is checked. The second operator records appropriate data for Quality Assurance documentation.
ASSEMBLY OF ACCESSORIES

The packing list will detail any accessories removed for shipment. The openings on the UZD® for these devices have been fitted with shipping covers. Remove the shipping covers, and check that the O-ring gaskets are securely pressed into the bottom of the flange grooves. A light coating of white petroleum jelly will help prevent pinching of the gasket. Follow tightening torques per the Torque Values shown in Table 4.

TABLE 4: TORQUE VALUES TABLE

<table>
<thead>
<tr>
<th>BOLT SIZE</th>
<th>GRADE 2</th>
<th>GRADE 5</th>
<th>GRADE 8</th>
<th>18-8 STAINLESS</th>
<th>BRASS</th>
<th>SILICON BRONZE</th>
<th>2024-T2 ALUMINUM</th>
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<tr>
<td>1/4 - 20</td>
<td>66</td>
<td>96</td>
<td>144</td>
<td>75</td>
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<td>1-14</td>
<td>240</td>
<td>640</td>
<td>1000</td>
<td>259</td>
<td>212</td>
<td>240</td>
<td>166</td>
</tr>
<tr>
<td>1-1/8-7</td>
<td>300</td>
<td>800</td>
<td>1280</td>
<td>413</td>
<td>337</td>
<td>383</td>
<td>265</td>
</tr>
<tr>
<td>1-1/8-12</td>
<td>340</td>
<td>880</td>
<td>1440</td>
<td>390</td>
<td>318</td>
<td>361</td>
<td>251</td>
</tr>
<tr>
<td>1-1/4-7</td>
<td>420</td>
<td>1120</td>
<td>1820</td>
<td>583</td>
<td>428</td>
<td>485</td>
<td>336</td>
</tr>
<tr>
<td>1-1/4-12</td>
<td>460</td>
<td>1240</td>
<td>2000</td>
<td>480</td>
<td>394</td>
<td>447</td>
<td>308</td>
</tr>
<tr>
<td>1-1/2-6</td>
<td>740</td>
<td>1940</td>
<td>3160</td>
<td>888</td>
<td>727</td>
<td>822</td>
<td>570</td>
</tr>
<tr>
<td>1-1/2-12</td>
<td>840</td>
<td>220</td>
<td>3560</td>
<td>703</td>
<td>575</td>
<td>651</td>
<td>450</td>
</tr>
</tbody>
</table>

**Conversion of Metric measures of torque:**

Every effort has been made to present torque measurements in this instruction book in the English system. Should you be confronted, for some reason, with a metric value the following conversion applies:

- Nm times 8.85 = inch pounds
- Nm times 0.738 = foot pounds
- kpm times 86.8 = inch pounds
- kpm times 7.23 = foot pounds
The UZD® is designed to maintain a gas space above the oil to allow for oil volume changes due to temperature. The UZD® tank holds 100 gallons of oil for temperatures down to –25°C. For temperatures between –25°C and –40°C, an offset in the float arm of the liquid level gauge is provided so the tank can hold 102 gallons of oil.

The standard liquid level gauge has one alarm contact to operate at low oil level but above critical oil level. An optional second alarm contact can be provided to operate at the critical low oil level or to indicate high oil level. Contacts at the critical low oil level are typically used to trip the transformer off-line to prevent arcing fault from occurring inside the LTC.

Air above the oil must be vented to the atmosphere to allow arcing gasses to escape. Air above the oil must also be dehydrated so the oil stays dry. To accomplish this, SPX Waukesha recommends an Auto-Recharging Dehydrating Breather (ARDB2) be used on the UZD®. The ARDB2 uses silica gel to remove moisture from the air, features a built-in heater that turns on periodically to dry the silica gel and is typically mounted at eye level for ease of inspection, Figure 49 and 50. A 16.5 foot length of flexible tubing is provided to connect the UZD® to the ARDB2. Clips should be provided on the transformer by the OEM to restrain the tubing. There are studs behind and to the top and bottom of the spring drive compartment and behind and to the top of the BUE which can be used to secure breather tubing.

The ARDB2 (or any silica gel breather) should be disconnected from the UZD® during oil draining or filling. Oil or oil vapor can coat the gel and prevent it from absorbing moisture. If the ARDB2 (or other silica gel breather) is not disconnected during oil draining or filling, the silica gel should be replaced. Be sure to reconnect the ARDB2 after oil filling.

For further information about the ARDB2 visit the Components/Transformer Health Products’ section of www.spxtransformersolutions.com or contact your SPX Waukesha Channel Partner.

If the UZD® will be filled with natural ester fluid, SPX Waukesha recommends that a Nitrogen Generator be used to bleed a small amount of nitrogen across the gas space in the UZD® to, 1) sweep away arcing gasses generated, and 2) exclude oxygen and water vapor from entering the UZD® gas space. In this case, an ARDB or other silica gel breather is not required. Contact SPX Waukesha for further information about this arrangement.
ON-LINE OIL FILTRATION USING THE OF2

To keep the oil clean of arcing particles, SPX Waukesha recommends the use of the OF2 on-line Oil Filtration System, Figures 51A, 51B and 51C. Keeping the oil clean and dry will extend contact life and can extend the time between internal inspections. For further information, visit the Components/Transformer Health Products’ section of www.spxtransformersolutions.com or contact your SPX Waukesha Channel Partner.
ENCLOSED OIL FILTRATION SYSTEM SPECIFICATIONS

GENERAL:
Ambient Temperature Range: from -40°C to 50°C
Fluid Operation Temperature: > -10°C to 150°C
Dimensions: 33.5"W x 13.7D x 34.5"H
Color: ANSI 61 Standard, Others Available
Oil Inlet: Convenient Input 3-way Valve for Addition of Oil Make-Up and Sample Collections
  With Inlet Y-Strainer to Protect Pump From Large Debris.
Oil Outlet: Window Visible Flow Indicator (Paddle Wheel)
Mounting: Pad or Wall Mount

ENCLOSURE:
Type: Standard With Custom NEMA 3R; Stainless Steel Optional
Latch: 3 Way Latching System per UL Requirements
Enclosure Anti-Condensation: Efficient 120 VAC Thermostat-Free, High Recovery PTC2 heater (200/400 watts)
Fluid Heater (optional): Optional Proprietary Designed PTC Canister Heaters - Cannot Overheat Fluids
Venting: Duct Filters Both Sides of Cabinet
Documentation: Pocket for Operation Instructions Provided Inside of the Cabinet Door

PUMP/MOTOR:
Canister: 7x18 Compliant With Most Major Replacement Depth Filters
  : Unique Tilt-Out Canister Design to Allow for Tool-Less Filter Maintenance
  : Air Vent Valve and Flexible Drain Tube Allow Spill-Free Filter Changes
Filter: Depth Filter Water and Particulate Standard. Others Available
  : Axial Flow Maintains Fluids at 12/10 ISO or NAS 4, ßS=500, ß3=150
  : 3 Micron Absolute, Less Than 1 Micro Particle Removal, 0.5 Micron When Loaded
  : Reduces Water to Less Than 15 ppm

CONTROLS:
Standard Controls: 1-160 psi Oil Filled Gauge and Visible Flow Indicator
  : High Pressure Output Alarm Wired to Alarm Contact and Latching Relay
  : System Designed For Continuous Operation, Timer Option is also Included
Electrical: 120 VAC Single Phase. Transformer for 230 VAC Operation Available
  : Automatic System Restart After Power Interruption
  : Relay Provided for Remote Shutdown
  : Optional Run Cold Circuit Available, Runs System Continuously Below 20°F
FIGURE 5C: OIL FILTRATION SYSTEM (2ND GENERATION) – OF2

Oil Filtration Systems

**OF2 - XXXXXXXX**

- **SYSTEM TYPE**
  - STANDARD SYSTEM (120VAC)
  - STEEL NEMA 3R CAB
  - 1/2 HP MOTOR
  - 5 GAL LEAK DETECTION
  - VISUAL FLOW INDICATOR
  - 0-100 PSI OIL FILLED GAGE
  - RUN INTERVAL TIMER
  - RUN-TIME METER
  - AUTO RESTART WITH POWER FAILURE

- **FILTER PACKAGE**
  - SAME AS OPTION "A" EXCEPT FOR 400 VAC OPERATION
  - 34.98 38.57 33.37
  - SAME AS OPTION "D" EXCEPT WITH STAINLESS STEEL CAB & 240VAC OPERATION

- **PUMP CAPACITY**
  - 1 GALLON PER MIN.
  - MECH. SEALS
  - INTEGRAL BYPASS

- **LOW FLOW / LEAK ALARMS**
  - SAME AS OPTION "A" EXCEPT WITH FLOW TRANSMITTER (4-20 mA)

- **HIGH PRESSURE ALARMS**
  - SAME AS OPTION "D" EXCEPT WITH PRESSURE TRANSMITTER (4-20 mA)

- **AMBIENT TEMPERATURE RANGE**
  - 0°F TO 122°F

- **PIPING**
  - MAX. 7 X 18 DEPTH
  - SAME AS OPTION "D" EXCEPT WITH STAINLESS STEEL CAB & 240VAC OPERATION
  - 240VAC - 120VAC TRANSFORMER

- **STANDARD SYSTEM (120VAC)**
  - STEEL NEMA 3R CAB
  - 1/2 HP MOTOR
  - 5 GAL LEAK DETECTION
  - VISUAL FLOW INDICATOR
  - 0-100 PSI OIL FILLED GAGE
  - RUN INTERVAL TIMER
  - RUN-TIME METER
  - AUTO RESTART WITH POWER FAILURE

- **STANDARD HIGH PRESSURE DETECTION WITH LOCAL LED INDICATOR AND ALARM CONTACTS**

- **STANDARD HIGH PRESSURE DETECTION WITH LOCAL WINDOW VISIBLE LED INDICATOR SYSTEM SHUTDOWN, AND ALARM CONTACTS**

- **SAME AS OPTION "A" EXCEPT WITH FLOW TRANSMITTER (4-20 mA)**
  - 0-100 PSI OIL FILLED GAGE
  - RUN INTERVAL TIMER
  - RUN-TIME METER

- **SAME AS OPTION "A" EXCEPT WITH PRESSURE TRANSMITTER (4-20 mA)**

- **SAME AS OPTION "A" EXCEPT WITH FLOW TRANSMITTER (4-20 mA)**

- **SAME AS OPTION "A" EXCEPT WITH PRESSURE TRANSMITTER (4-20 mA)**
PRESSURE SWITCH

General
The pressure switch is designed to indicate excessive pressure in the tap changer switching compartment if a fault should occur. It is the function of the pressure switch to send a signal to transformer protective equipment to remove the transformer from the system in the event of a fault in the tap changer.

Design and Operation
As shown in Figure 52, the pressure switch assembly consists of a ball valve 1, street tee 2, relay housing 3 and pipe plug 4.

The relay housing, as shown in Figure 53, contains the pressure sensor with diaphragm, piston, spring, adjusting nut and switching element.

Under normal operating conditions the switch will operate in less than 5ms.

When the oil pressure on the area of the piston exceeds the spring load on the piston, the piston will move toward the switching element, thus actuating it. For electrical connection a terminal block is provided on the switching element.

We recommend this be connected to trip the main circuit breaker. The transformer should be taken out of service and the tap changer inspected in the event of operation of the pressure switch.
**Mounting and Connection**

The pressure switch is mounted to a flange on the tap changer switching compartment. Electric connection should be made to an intermediate lockout relay with a main breaker. Electrical rating of the switch is 125/250/480 VAC, 15 A and 24-30 VDC, 2 A resistive and 1 A inductive. At 125 VDC, 0.5 A resistive and 0.03 A inductive.

**Adjusting and Testing**

The switch has a setting range from 1 psi to 20 psi. All pressure relays are preset at the factory to close at 4.3 psi ±5%. When the tap changer Major Inspection is carried out or during regular routine inspections a test of the operating pressure should be made. For this purpose a ball valve is provided. The test is carried out with a pressure gauge in combination with an air pump connected to the test tap. The pressure setting is adjusted by variation of the spring load on the piston through the adjusting nut.

To adjust the pressure set point remove cover. Loosen Phillips screw adjustment lock. Adjust set point by turning 5/8” hex adjustment screw clockwise (left) to raise set point, or counter clockwise (right) to lower set point. Retighten adjustment lock.

See Pressure Switch section under Annual Inspections in the UZD® Field Maintenance manual for further instructions.
### LTC OIL

New mineral oil should be used to fill the UZD® and meet the specified values detailed below:

#### TABLE 5: RECOMMENDED MINERAL OIL SPECIFICATIONS

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTIES</th>
<th>ASTM TEST METHOD</th>
<th>ANSI /ASTM D-3487 LIMITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aniline point, °C</td>
<td>D611</td>
<td>63-84</td>
</tr>
<tr>
<td>Color</td>
<td>D1500</td>
<td>0.5 max</td>
</tr>
<tr>
<td>Flash point, °C</td>
<td>D92</td>
<td>145 min</td>
</tr>
<tr>
<td>Interfacial tension @ 25°C (dynes/centimeter)</td>
<td>D971</td>
<td>40 min</td>
</tr>
<tr>
<td>Pour point, °C</td>
<td>D97</td>
<td>-40 max</td>
</tr>
<tr>
<td>Specific gravity @ 15°C/15°C</td>
<td>D1298</td>
<td>0.91 max</td>
</tr>
<tr>
<td>Viscosity, SSU/cSt @ 100°C</td>
<td>D88/D445</td>
<td>36/3.0 max</td>
</tr>
<tr>
<td>Viscosity, SSU/cSt @ 40°C</td>
<td></td>
<td>66/12.0 max</td>
</tr>
<tr>
<td>Viscosity, SSU/cSt @ 0°C</td>
<td></td>
<td>350/76.0 max</td>
</tr>
<tr>
<td>Polychlorinated Biphenyls (PCBs) ppm</td>
<td>D-4059</td>
<td>Not Detectable</td>
</tr>
<tr>
<td>Visual appearance</td>
<td>D1524</td>
<td>Clear and Bright</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHEMICAL PROPERTIES</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved antioxidant content, wt %</td>
<td>D2668, D1473</td>
<td>0.30 max</td>
</tr>
<tr>
<td>Corrosive sulfur</td>
<td>D1275 Modified 1</td>
<td>Noncorrosive</td>
</tr>
<tr>
<td>Moisture, ppm</td>
<td>D1315, D1533</td>
<td>35 max</td>
</tr>
<tr>
<td>Neutralization number, mg KOH/g of oil</td>
<td>D974</td>
<td>0.03 max</td>
</tr>
<tr>
<td>Oxidation stability Method A (acid/sludge test)</td>
<td>D2440</td>
<td></td>
</tr>
<tr>
<td>72 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sludge, wt %</td>
<td></td>
<td>0.10 max</td>
</tr>
<tr>
<td>Neutralization value, mg KOH/g</td>
<td></td>
<td>0.30 max</td>
</tr>
<tr>
<td>164 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sludge, wt %</td>
<td></td>
<td>0.20 max</td>
</tr>
<tr>
<td>Neutralization value, mg KOH/g</td>
<td></td>
<td>0.40 max</td>
</tr>
<tr>
<td>Method B (rotary bomb oxidation test)</td>
<td>D2112</td>
<td>195 min.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ELECTRICAL PROPERTIES</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric breakdown voltage at 60 hertz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disc electrodes, kV</td>
<td>D877</td>
<td>30 min</td>
</tr>
<tr>
<td>VDE electrodes, kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ 0.040-in. gap or</td>
<td>D1816*</td>
<td>28 min</td>
</tr>
<tr>
<td>@ 0.080-in. gap</td>
<td>D1816*</td>
<td>56 min</td>
</tr>
<tr>
<td>Dielectric breakdown voltage 25°C impulse conditions, kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Needle (negative)-to-sphere (grounded)</td>
<td>D3300</td>
<td></td>
</tr>
<tr>
<td>@ 1-in gap</td>
<td></td>
<td>145 min</td>
</tr>
<tr>
<td>Power factor at 60 hertz, % at:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25°C</td>
<td>D924</td>
<td>0.05 max</td>
</tr>
<tr>
<td>100°C</td>
<td>D924</td>
<td>0.30 max</td>
</tr>
<tr>
<td>Gassing Tendency @ 80 °C (µL/min)</td>
<td>D-2300 B</td>
<td>+ 30 max</td>
</tr>
</tbody>
</table>

*D1816 only applies to new oil that has been filtered, dehydrated and degassed.*
Oil shall be PCB-free according to existing current law. Properties as listed are only attainable on new oil as received from the refinery. Oil contained in equipment as received from the manufacturer, when properly sampled from such equipment, typically exhibits characteristics slightly different from those obtained from new oil that has not been in contact with apparatus/constructional materials. In such cases, the oil should be evaluated per IEEE C57.106 (most recent release) for acceptance and maintenance of insulating oil in equipment.

**Acceptance Test**

Samples for testing are to be obtained and tested in accordance with the latest issue of ASTM test methods (currently ASTM Test Method D923).

**Determination of Quantity**

The usual temperature for measurement of oil delivered under this specification is established at a 15.5°C basis in accordance with the standard abridged volume or correction table for petroleum oil, ASTM D1250.

**Oil Filling Procedure**

Never fill UZD® tap changers while transformer is in its vacuum cycle!

UZD® tap changers must be vented during oil filling. To vent, either remove hose to breather or remove Rapid Pressure Rise relay (RPR)/cover plate. In either case, make sure the breather is disconnected so that any oil vapor does not contact the silica gel as oil coating on the gel prevents it from absorbing moisture.

The UZD® holds 100 US gallons of oil. The cold temperature option for the UZD® holds 102 US gallons.

Zero out oil counter. Fill LTC with oil through the oil drain valve at bottom left side of UZD® tank. Fill to the 25°C mark on the liquid level gauge, also indicated below. This assumes 25°C. If oil is other than 25°C adjust for temperature. Close valve when level has been reached. Shut off oil at pumping station.

Taking regular oil samples from LTCs for use in Dissolved Gas Analysis and Oil Quality tests is becoming commonplace. As such, you may want to add some additional oil to the UZD® to allow for some additional samples to be removed before make up oil has to be added. It is permissible to fill the UZD® tank with 102 gallons of oil. The liquid level gauge will read above the 25°C mark when this extra oil is added. The information provided below shows the oil level, oil level float arm angle and oil level for both 3.5 and 6 inch diameter liquid level gauges and for both 100 and 102 gallons of fluid at various temperatures.

<table>
<thead>
<tr>
<th><strong>TABLE 6: 3.5 INCH DIAMETER LIQUID LEVEL GAUGE SETTINGS &amp; VOLUMES</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.5 INCH DIAMETER LIQUID LEVEL GAUGE</strong></td>
</tr>
<tr>
<td><strong>UZD® TANK OIL VOLUMES</strong></td>
</tr>
<tr>
<td>Oil Temperature</td>
</tr>
<tr>
<td>90</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>-50</td>
</tr>
<tr>
<td><strong>UZD® LIQUID LEVEL GAGE SETTINGS</strong></td>
</tr>
<tr>
<td>Float Length =</td>
</tr>
<tr>
<td>Float Arm Length =</td>
</tr>
<tr>
<td>90</td>
</tr>
<tr>
<td>-50</td>
</tr>
<tr>
<td>TRIP</td>
</tr>
<tr>
<td><strong>UZD® TANK OIL VOLUMES</strong></td>
</tr>
<tr>
<td>Oil Temperature</td>
</tr>
<tr>
<td>90</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>-20</td>
</tr>
<tr>
<td><strong>UZD® LIQUID LEVEL GAGE SETTINGS</strong></td>
</tr>
<tr>
<td>Float Length =</td>
</tr>
<tr>
<td>Float Arm Length =</td>
</tr>
<tr>
<td>90</td>
</tr>
<tr>
<td>-20</td>
</tr>
<tr>
<td>TRIP</td>
</tr>
</tbody>
</table>
The "cold" tank is good to -50°C. Oil volume of "Cold" temp tank is 102 gallons, this requires an offset in the float arm to add the additional 2 gallons of oil at 25°C. Oil changes in volume $0.000774$ cubic inches per °C (approximate value at the normal temperature range of the LTC). Tank dimensions at the top is 36" X 17.5" = 630 square inches. One gallon of liquid is 231 cubic inches. For a 10° increase ($10 \times 0.000774 \times 102 \text{ gal} = 0.78948$ increase. Volume change then is $(789 \times 231) = 182.37$ cubic inch increase.

Every one-inch of oil in this part of the tank is 630 cubic inches. Therefore $(182.37 \text{ cu/in} / 630 \text{ sq/in}) = 0.289$ inch change in oil level per 10 °C.

The motor drive mechanism must be protected against condensation. Whenever control power is available, the heater should be energized. When power is not available, use of a drying agent in the motor drive compartment will suffice as long as the vents are sealed.

The UZD® can be shipped with oil in the oil-filled compartment, independent of whether or not oil is located in the main transformer tank. Shipping the load tap changer oil-filled simplifies the field assembly process, unless an internal LTC field inspection will be completed upon receipt.

Do not energize the transformer until both the transformer and UZD® have been properly filled with oil.
ELECTRICAL CONNECTION AND TESTING

General
Before the transformer is energized, testing should be performed to verify that all mechanical and electrical connections are correct and the load tap changer motor and drive mechanism are functioning properly. When testing the transformer, the load tap changer can be operated either electrically or manually by use of the hand crank.

Shipping
The light bulb and its enclosure in the BUE motor drive mechanism should be removed from its socket and wrapped in bubble wrap or sheet foam then secured in the BUE compartment for shipment of the transformer. Failure to do this may result in damage.

Connecting and Testing
Connect the power supply for the motor, controls and auxiliary devices as shown on the schematic provided with the load tap changer. Connect to all alarm contacts per this same schematic.

Operate the motor drive mechanism by means of the hand crank to one of the tap positions in the middle of the range but not a through-position (a through-position typically includes a letter, such as RN). Turn the control selector switch to the LOCAL position and give an impulse for a RAISE operation. Verify the tap changer moves in the raise direction. Continue to the 15R position. Use the hand crank to move the tap changer to position 16R and verify that the normally-closed contact on limit switch LS-1 opens to block current to the drive motor. This can be done on the terminals of LS-1 (see schematic Figure 21, page 34 for terminal identification). Continue to operate the tap changer manually for another turn or two and verify that the mechanical end stop operates (preventing further movement).

Operate manually back to 16R. An in-service position is attained when the flag indicator in the motor drive mechanism is in the center of travel below the word POSITION. Then operate manually or electrically to 15L and repeat the above procedure.

Electrical Tests on Transformer
Factory testing on the transformer can now be performed.

FIELD COMMISSIONING

Reassemble any accessories that have been removed for shipment. If the load tap changer was shipped without oil, fill with oil as described in the Oil Filling procedure in the Major Inspection section of the Field Maintenance Manual.

Ensure the Auto-Recharging Dehydrating Breather (ARDB2) is connected to the oil-filled compartment and electrically wired to receive control power. Turn control power to the ARDB2 off and then on again to start a regeneration cycle. Verify warm up of the ARDB2.

Confirm the OF2 oil filtration system is connected to the oil-filled compartment and electrically wired to receive control power. Turn the filter on and verify flow and proper operating pressure.

All inspections as described in the ANNUAL INSPECTION section of the UZD® Maintenance Manual should be performed prior to the transformer being energized on site.

Verify that the LOCAL/REMOTE switch is in the desired setting.
Glossary

**Arcing switch:** A switching device used in conjunction with a tap selector to carry, make and break current in circuits that have already been selected.

**ARDB:** Waukesha brand name for Auto-Recharging Dehydrating Breather, a self recharging silica gel breather that dehydrates air going into a compartment.

**Arcing tap switch:** A switching device capable of carrying current and also breaking and making current while selecting a tap position, thereby combining the duties of an arcing switch and a tap selector. Also used interchangeably in this manual as a Selector Switch.

**Circulating current:** Current that flows through the transition impedance or reactor as a result of two taps being bridged during a tap change operation.

**Cycle of operation:** Movement of the LTC from one end of its range to the other and back to its original position.

**Design test:** Test performed on an LTC or the components of an LTC to prove compliance with standards.

**Drive mechanism:** Means by which the LTC is actuated.

**Insulation level:** Withstand values of the impulse and power frequency test voltages to ground and, where appropriate, between the phases and between those parts where insulation is required.

**Load tap changer (LTC):** A selector switch device, which may include current interrupting contactors, used to change transformer taps with the transformer energized and carrying full load.

**Main contacts:** For resistance-type LTCs, a set of through current-carrying contacts that has no transition impedance between the transformer winding and the contacts and commutates the current to the main switching contacts without any arc.

**Main switching contacts:** For resistance-type LTCs, a set of contacts that has no transition impedance between the transformer winding and the contacts and makes and breaks current.

**Maximum rated step voltage:** Highest value of rated step voltage for which the LTC is designed.

**Maximum rated through current:** The rated through current for which both the temperature rise of the contacts and the service duty test apply.

**Number of inherent tap positions:** The highest number of tap positions for half a cycle of operation for which an LTC is designed.

**Number of service tap positions:** Number of tap positions for half a cycle of operation for which an LTC is used in a transformer.

**OF2:** Waukesha brand name for it’s oil filtration system

**Plus/minus operation:** A winding arrangement in which one or the other end of the tap winding is connected by a reversing change-over selector to the main winding and allows use of the taps in a buck or boost mode when travelling through the tapping range.
**Rated frequency:** Frequency of the alternating current for which the LTC is designed.

**Rated step voltage:** For each value of rated through current, the highest permissible voltage between successive tap positions.

*NOTE:* Step voltage of resistance-type LTCs means tap-to-tap voltage (no bridging position).

**Rated through current:** The current flowing through the LTC toward the external circuit, which the apparatus is capable of transferring from one tap to another at the relevant rated step voltage and which can be carried continuously while meeting the requirements of stated standards.

*NOTE:* Within the maximum rated through current of the LTC, there may be different assigned combinations of values of rated through current and corresponding rated step voltage. When a value of rated step voltage is referred to as a specific value of rated through current, it is called the relevant rated step voltage.

**Recovery voltage:** Voltage that appears across each set of main switching, or transition, contacts of the arcing switch or arcing tap switch after these contacts have broken the switched current.

**Relevant rated step voltage:** The value of rated step voltage that corresponds to a specific value of rated through current.

**Reversing change-over selector:** A change-over selector that connects one or the other end of the tap winding to the main winding.

**Reversing switch:** Another commonly used name for reversing change-over selector.

**Routine test:** A test made on each completed LTC to establish that the LTC is without manufacturing defects, with the design having been verified by a design test.

**Switched current:** Prospective current to be broken during a switching operation by each set of main switching or transition contacts or vacuum interrupters (resistance-type LTC) incorporated in the arcing switch or arcing tap switch.

**Tap change operation:** Complete sequence of events from the initiation to the completion of the transition of the through current from one tap position to an adjacent one.

**Tap selector:** Device designed to carry, but not to make or break, current, used in conjunction with an arcing switch to select tap connections.

**Transition contacts:** For resistance-type LTCs, a set of contacts that is connected in series with a transition impedance and makes and breaks current.

**Transition impedance:** A resistor or reactor consisting of one or more units that bridge adjacent taps for the purpose of transferring load from one tap to the other without interruption or appreciable change in the load current, at the same time limiting the circulating current for the period that both taps are used. Normally, reactance-type LTCs use the bridging position as a service position, and, therefore, the reactor is designed for continuous loading.
FIGURE NUMBERS

Figure 1: UZD® with BUE Unit Attached ...................................... 6
Figure 2: Cast Epoxy Phase Molding with Contacts Assembled . . 7
Figure 3: Stationary Contact .................................................. 9
Figure 4: Main Moving Contact Assembly with Transition Resistor ........................................................... 9
Figure 5: Reversing Change-Over Selector (Reversing Switch) . . . 10
Figure 6: Main Switch and Spring Drive Compartment ............... 11
Figure 7A: Spring Drive Mechanism ......................................... 13
Figure 7B: Exploded Spring Drive Mechanism .............................. 15
Figure 8A: Dimensions for External UZD® Tank .......................... 16
Figure 8B: Dimensions for Mounting Bracket on Bottom of BUE to Transformer Tank Wall Used with Offset Shaft Extension ....... 17
Figure 8C: Dimensions for Conduit Entrance in Back of BUE ...... 17
Figure 8D: Typical Location of UZD® on Transformer ................. 17
Figure 8E: Detail of Tank Opening ............................................ 17
Figure 8F: Detail of Phase Molding Extension Into Transformer Tank .......................................................... 18
Figure 8G: Detail of UZD® Mounting Flange ............................... 18
Figure 9: BUE Cabinet ............................................................ 21
Figure 10A: Motor Drive Mechanism - Exploded View ............... 22
Figure 10B: Motor Drive Mechanism ......................................... 23
Figure 10C: Motor Drive Mechanism - Exploded View ............... 25
Figure 11-18: Stationary Contact Positions .................................. 28-30
Figures 19A-C: Reversing Change-Over Selector for Plus/Minus Switching..................................................... 32
Figure 20A: LTC and Transformer Winding Connections with Series Transformer ................................................ 33
Figure 20B: LTC and Transformer Winding Connections without Series Transformer ............................................ 33
Figure 20C: LTC and Transformer Winding Connections with Auto Connected Series Transformer .......................... 33
Figure 20D: Connection Diagram ............................................. 33
Figure 21: Control Schematic .................................................... 34
Figure 22: Control Schematic - Device Legends .......................... 35
Figure 23: Contact Timing Diagram .......................................... 37
Figure 25: UZD® LTC Name Plate ............................................ 39
Figure 26: Motor Drive Name Plate ........................................... 39
Figure 27: Step Voltage vs. Rated Through-Current ..................... 40
Figure 28: Predicted Contact Life with Breaking Currents ............. 40
Figure 29: Small Cable Lug, 1 AWG ........................................ 40
Figure 30: Medium Cable Lug, 4/0 AWG ................................... 42
Figure 31: Large Cable Lug, 300 MCM .................................... 42
Figure 32: Alignment of Tap Changer ........................................ 44
Figure 33: Weld Requirement ................................................... 45
Figure 34: Direct Mount of BUE Below the UZD® ......................... 45
Figure 35: Offset Mount of BUE Below the UZD® ......................... 46
Figure 36-37: BUE Locking Device ........................................... 47
Figure 38-39: Disc Brake Wheel and Brake Shoe Alignment .......... 47
Figure 40: Spring Drive Mechanism and BUE Drive Shaft Alignment .......................................................... 48
Figure 41: Drive Arm Position in Neutral .................................... 48
Figure 42: Selector Switch Position in Neutral .............................. 48
Figure 43: BUE and LTC Coupling ............................................ 49
Figure 44: LTC Leads Before Connections .................................. 50
Figure 45: LTC Labeling .......................................................... 50
Figure 46 - 47: Copper Lead Installation ..................................... 51
Figure 48: LTC Leads with Connections Completed .................... 51
Figure 49-50: Breather and Breather Installation Kit Drawing ... 54
Figure 51A-C: Oil Filtration System - OF2 Kit Drawing ......... 55-57
Figure 52: Pressure Switch ...................................................... 58
Figure 53: Relay Housing ........................................................ 59
Figure 54: Oil Level Gauge ...................................................... 62

TABLE NUMBERS

Table 1: Electrical Ratings ...................................................... 38
Table 2: Estimated Contact Life ................................................ 40
Table 3: Available Cable Lug Sizes .......................................... 42
Table 4: Torque Values Table .................................................... 52
Table 5: Recommended Mineral Oil Specifications ....................... 60
Table 6: 3.5 Inch Diameter Liquid Level Gauge Settings & Volumes ............................................. 61
Table 7: 6.0 Inch Diameter Liquid Level Gauge Settings & Volumes ............................................. 62
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