ANSI® C57.12.10-1988
Revision and Consolidation of ANSI C57.12.10-1977, C57.12.10a-1978, and C57.12.30-1977

American National Standard for Transformers — 230 kV and Below 833/958 through 8333/10 417 kVA, Single-Phase, and 750/862 through 60 000/80 000/100 000 kVA, Three-Phase without Load Tap Changing; and 3750/4687 through 60 000/80 000/100 000 kVA with Load Tap Changing — Safety Requirements

Secretariat

Institute of Electrical and Electronics Engineers
on National Electrical Manufacturers Association

Approved June 4, 1987

American National Standards Institute, Inc

Foreword

(This Foreword is not part of American National Standard C57.12.10-1988.)

American National Standard C57.12.10 was first approved in 1958 and represented the first product standard for power transformers. It originally encompassed transformers 501 through 10 000 kVA with a maximum voltage of 67 000 volts. Successive revisions gradually expanded the scope, and subsequently a companion standard, ANSI C57.12.30, was added for power transformers with load-tap-changing equipment.

This standard is a revision and consolidation of ANSI C57.12.30-1977, Requirements for Load-Tap-Changing Transformers 230 000 Volts and Below, 3750/4687 through 60 000/80 000/100 000 kVA, Three-Phase; ANSI C57.12.10-1977 and C57.12.10a-1978, Requirements for Transformers 230 000 Volts and Below, 833/958 through 8333/10 417 kVA, Single-Phase, and 750/862 through 60 000/80 000/100 000 kVA, Three-Phase. Some of the changes in this revision are the:

1) Combining of ANSI C57.12.10-1977 and C57.12.30-1977 into s single document.
2) Reorganizing of the data included in the two previous documents to eliminate repetition of much almost-identical data. Construction features are now described only once.
3) Reorganizing to better recognize small three-phase power transformers (750-2500 kVA) with distribution insulation levels (see Tables 8 and 9), and reduced construction features (see Table 11, “Basic Standard” Construction Features, 750-2500 Distribution BILs.)

It is anticipated that this simpler, briefer section on construction will eventually make the conversion to primary use of metric system international dimensions simpler and easier.

Other changes in the 1988 revision include numerous editorial changes to update information and references. A few nominal system voltages have been revised slightly to conform to the voltages of ANSI C84.1-1982, and are coded to indicate those which are recognized in ANSI C84.1-1982, Voltage Ratings for Electric Power Equipment (60 Hz). Manual taps have been changed to the very commonly used two 2.5-percent taps above and two 2.5-percent taps below rated high voltage. Paralleling systems for load-tap-changing transformers have been added as an “other” item. Recommended accuracy classifications of bushing current transformers for relaying service have been added. The percent impedance values of 60-150 BIL have been added. The percent impedance values of 60-150 BIL transformers have been reduced. The standard connection for shipment of series/ multiple windings (when provided) was determined to be the “multiple” connection. In addition to these changes, many minor updating items and changes intended to improve format, organization, clarity, and brevity have been introduced.

This standard is a voluntary consensus standard. Its use is mandatory only when required by a duly constituted legal authority or when specified in a contractual relationship. To meet specialized needs and to allow innovation, specific changes are permissible when mutually determined by the user and the producer, provided such changes do not violate existing laws and are considered technically adequate for the function intended.

When this document is used on a mandatory basis, the words “shall” and “must” indicate mandatory requirements, and the words “should” and “may” refer to matters that are recommended and permitted, respectively, but are not mandatory.

Suggestions for improvement of this standard will be welcomed. They should be sent to the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037.

The standard was processed and approved for submittal to ANSI by the Accredited Standards Committee on Transformers, Regulators, and Reactors, C57. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the C57 Committee had the following members:

Subcommittee C57.12.1 on Power Transformers, which developed and approved this standard had the following members:

K. Linsley, *Chair*
C. H. White, *Secretary*

R. Alton
S. Bennon
F. Cook, Sr
C. Dixon
J. Douglass
J. Dutton
G. Gunnels
R. Hollister *(Alt)*
O. Keller
H. Light
K. Linsley
L. Long
J. McGill
W. McNutt
P. Nelson
D. Peacock
W. Richter
L. Smith
D. Soffrin
H. Stickley
R. Toler
D. Torgerson

CLAUSE PAGE

American National Standard for Transformers — 230 kV and Below 833/958 through 8333/10 417 kVA,Single-Phase, and 750/862 through 60 000/80 000/100 000 kVA, Three-Phase without Load Tap Changing; and 3750/4687 through 60 000/80 000/100 000 kVA with Load Tap Changing — Safety Requirements

1. Introduction, Scope, and Organization

1.1 Introduction

This voluntary consensus standard is intended for use as a basis for performance, interchangeability, and safety of equipment covered, and to assist in the proper selection of such equipment.

1.2 Scope

This standard covers certain electrical, dimensional, and mechanical characteristics and takes into consideration certain safety features of 60-Hz, two-winding, liquid-immersed transformers rated as follows, and used for step-down purposes:

1) 833/958 through 8333/10 417 kVA, single-phase; 750/862 through 10 000/12 500 kVA, three-phase; high voltage, 2400 through 138 000 volts; low-voltage, 480 through 36 230 volts; without load tap changing

   NOTE — A subgroup of the above group is also identified as three-phase transformers 750-2500 kVA, with distribution BIL characteristics.

2) 12 000/16 000/20 000 through 60 000/80 000/ 100 000 kVA, three-phase; high voltage, 23 000 through 230 000 volts; low voltage, 4800 through 36 230 volts; without load tap changing
3) 3750/4687 through 10 000/12 500 kVA, three-phase; high voltage, 6900 through 138 000 volts“, low voltage, 2400 through 36 230 volts; with load tap changing
4) 12 000/16 000/20 000 through 60 000/80 000/100 000 kVA, three-phase; high voltage, 23 000 through 230 000 volts; low voltage, 4800 through 36 230 volts; with load tap changing

It is not intended that this standard shall apply to dry-type, regulating, pad-mounted, secondary-network, furnace, rectifier, or mine transformers.

1.3 Organization

This standard is divided into two parts:

1) Part A: “Basic Standard” ratings, characteristics, construction, and routine tests
2) Part B: “Other” ratings, construction, and tests

1.4 Mandatory Requirements

When this standard is used on a mandatory basis, the words “shall” and “must” indicate mandatory requirements, and the words “should” and “may” refer to matters that are recommended and permitted, respectively, but not mandatory.

NOTE — The Foreword of this standard describes the circumstances under which the document may be used on a mandatory basis.

Part A: “Basic Standard” Ratings, Characteristics, Construction, and Routine Tests

2. Referenced and Related Standards

2.1 Referenced American National Standards

This standard is intended for use in conjunction with the following American National Standards. When the referenced standards are superseded by a revision approved by the American National Standards Institute, Inc, the latest revision shall apply:

ANSI B1.1-1982, Unified Inch Screw Threads (UN and UNR Thread Form)

ANSI C57.12.70-1978, Terminal Markings and Connections for Distribution and Power Transformers

ANSI C84.1-1982, Electric Power Systems and Equipment (60 Hz) - Voltage Ratings

ANSI/ASME B1.20.1-1983, Pipe Threads. General Purpose (Inch)

ANSI/IEEE 21-1976, General Requirements and Test Procedure for Outdoor Apparatus Bushings

ANSI/IEEE 24-1984, Performance Characteristics and Dimensions for Outdoor Apparatus Bushings

ANSI/IEEE 100-1984, Dictionary of Electrical and Electronics Terms

ANSI/IEEE C37.90.1-1974, Guide for Surge Withstand Capability (SWC) Tests

ANSI/IEEE C57.12.00-1987, General Requirements for Liquid.Immersed Distribution, Power and Regulating Transformers

ANSI/IEEE C57.12.80-1978, Terminology for Power and Distribution Transformers

ANSI/IEEE C57.13-1978, Requirements for Instrument Transformers

ANSI/IEEE C57.92-1981, Guide for Loading Mineral-Oil-Immersed Power Transformers

2.2 Related Standard

The following standard is listed for information only and is not essential for the completion of the requirements of this standard:

ANSI/IEEE C57.12.90-1987, Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers, and Guide for Short-Circuit Testing of Distribution and Power Transformers

3. Terminology

Standard transformer terminology in ANSI/IEEE C57.12.80-1978 shall apply. Other electrical terms are defined in ANSI/IEEE 100-1984.

4. Rating Data

4.1 Usual Service Conditions

Service conditions shall be in accordance with ANSI/IEEE C57.12.00-1987.

4.2 Kilovolt-Ampere Ratings

4.2.1

Kilovolt-ampere ratings are continuous and based on not exceeding either a 65°C average winding temperature rise by resistance or an 80°C hottest spot temperature rise, as covered in ANSI/IEEE C57.12.00-1987.

4.2.2

Kilovolt-ampere ratings shall be as listed in Tables 1 and 2.

4.3 Kilovolt-Ampere and Voltage Ratings

Kilovolt-ampere and voltage ratings for self-cooled transformers shall be as listed in Tables 3 through 6.

4.4 Insulation Levels

Basic impulse insulation levels (BILs) for transformers shall be as listed in Tables 7 through 9.

4.5 Taps

4.5.1 High Voltage Winding Taps for Deenergized Operation

The following four high-voltage rated kVA taps shall be provided: two (2) 2.5 percent above rated voltage, and two (2) 2.5 percent below rated voltage. Voltages and currents should be listed in accordance with 7.1.

4.5.2 Taps for Load-Tap-Changing Transformers

When a load-tap-changing transformer is specified, load-tap-changing equipment shall be furnished to provide approximately ±10-percent automatic adjustment of the low-voltage winding voltage in approximately 5/8-percent steps, with sixteen steps above and sixteen steps below rated low voltage. The transformer shall be capable of delivering rated kilovolt-amperes at the rated low-voltage position and on all positions above rated low voltage. The transformer shall be capable of delivering low-voltage current corresponding to rated low voltage at all positions below rated low voltage.

4.6 Impedance Voltage

4.6.1 Percent Impedance Voltage

The percent impedance voltage at the self-cooled rating as measured on the rated voltage connection shall be as listed in Table 10.

4.6.2 Tolerance on Impedance Voltage

The tolerance shall be as specified in ANSI/IEEE C57.12.00-1987.

4.6.3 Percent Departure of Impedance Voltage on Taps for Deenergized Operation

The percent departure of tested impedance voltage on any tap from the tested impedance voltage at rated voltage shall not be greater than the total tap voltage range expressed as a percentage of the rated voltage.

NOTE — This does not apply to load-tap-changing taps.

4.7 Top-Liquid Temperature-Range Limits

The transformer shall be suitable for operation over a range of top-liquid temperatures from –20 °C to +105°C, provided the liquid level has been properly adjusted to the indicated 25°C level.

NOTE — Operation at these temperatures may cause the mechanical pressure-vacuum bleeder device (5.7.2) to function to relieve excessive positive or negative pressures.

4.8 Routine Tests

4.8.1

“Routine Tests” shall be made in accordance with ANSI/IEEE C57.12.00-1987.

4.8.2

On load-tap-changing transformers, additional routine tests for load-tap-changing transformers listed in ANSI/IEEE C57.12.00-1987 shall be made.

Table 1—Kilovolt-Ampere Ratings, Self-Cooled (OA)

Single-Phase (kV) Without Load Tap Changing	Three Phase (kVA)	
	Without Load Tap Changing	With Load Tap Changing
833	750	—
1250	1 000	—
1667	1 500	—
2500	2 000	—
3333	2 500	—
5000	3 750	3 750
6667	5 000	5 000
8333	7 500	7 500
—	10 000	10 000

Table 2—Kilovolt-Ampere Ratings, Self-Cooled (OA), Forced-Cooled First-Stage, and Forced-Cooled Second-Stage Three-Phase (With, or Without, Load Tap Changing), 12 000–100 000 kVA

OA	First-Stage	Second-Stage
12 000	16 000	20 000
15 000	20 000	25 000
20 000	26 667	33 333
25 000	33 333	41 667
30 000	40 000	50 000
37 500	50 000	62 500
50 000	66 667	83 333
60 000	80 000	100 000

Table 3—Range of Voltage and Kilovolt-Ampere Ratings for Single-Phase Transformers, 833-8333 kVA

High-Voltage Ratings (V)	Low-Voltage Ratings (V)				
	480	**2400/4160Y,** *2520/4360Y,* **4800/8320Y,** **—** *5040/8720Y*	*6900/11 950Y,* **8355/23 08SPW** *7560/13 090Y,* **7620/13 200Y,** **—** **7970/13 800Y**	**23 555W** **12 600,** **13 200,** **13 800** ***14 400***	**14 400/24 940Y** **—** **34 500,** **19 920/34 500Y** **—** *20 920/36 230Y*
	Self-Cooled (OA) Kilovolt-Ampere Ratings (kVA)				
2400/4160Y	833	—	—	—	—
4800/8320Y	833	—	—	—	—
6900/11 950Y,	833, 1250	833-2500	—	—	—
6930/12 000Y,	—	—	—	—	—
7200/12 470Y,	—	—	—	—	—
7620/13 200Y,	—	—	—	—	—
7970/13 800Y	—	—	—	—	—
12 000, 13 200,	—	—	—	—	—
13 800	—	—	—	—	—
23 000	833, 1250	833-2500	833-2500	—	—
34 500	833, 1250	833-2500	833-3333	833-3333	—
46 000	833, 1250	833-2500	833-8333	833-8333	—
69 000	—	833-2500	833-8333	833-8333	—
115 000	—	2500	2500-8333	2500-8333	2500-8333
138 000	—	2500	2500-8333	2500-8333	2500-8333

NOTES:

1 — All voltages are Δ unless otherwise indicated.

2 — Kilovolt-ampere ratings separated by a dash indicate that all the intervening ratings listed in Table 1 are included. Kilovolt-ampere ratings separated by a comma indicate that only those listed are included.

3 — Bold type-voltages listed in ANSI C84.1-1982.

4 — Italics type-voltages not listed in ANSI C84.1-1982.

Table 4—Range of Voltage and Kilovolt-Ampere Ratings for Three-Phase Transformers, Without Load Tap Changing 750-10 000 kVA

High Voltage Ratings (V)	Low-Voltage Ratings (V)					
	480Y/277, **480**	**2400,***2520* **4160Y/2400,** *4360Y/2520*	**4800,***5040,* **8320Y/4800,** *8720Y/5040*	**6900,7200,***7560,* **12 470Y/7200,** *13 090Y/7560,* **13 200Y/7620,** **13 800Y/7970,**	**13 800,** **12 000,***12 600*, **13 200,***14 400*	**24 940GrdY/14 000** **34 500,** **34 500GrdY/19 920,** *36 230GrdY/20 920*
	Self-Cooled (OA) Kilovolt-Ampere Ratings (kVA)					
2400	750-1500	—	—	—	—	—
4160,4800	750-1500	—	—	—	—	—
6900,7200	750-2500	1000-3750	—	—	—	—
12 000	750-2500	1000-7500	—	—	—	—
12 470	—	—	—	—	—	—
13 200	—	—	—	—	—	—
13 800	—	—	—	—	—	—
23 000	—	1000-7500	1000-10 000	1000-10 000	—	—
34 500	—	1000-7500	1000-10 000	1000-10 000	1000-10 000	—
46 000	—	1500-7500	1500-10 000	1500-10 000	1500-10 000	—
69 000	—	1500-7500	1500-10 000	1500-10 000	1500-10 000	—
115 000	—	5000-7500	5000-10 000	5000-10 000	5000-10 000	5000-10 000
138 000	—	5000-7500	5000-10 000	5000-10 000	5000-10 000	5000-10 000

NOTES:

1 — All voltages are Δ unless otherwise indicated.

2 — Kilovolt-ampere ratings separated by a dash indicate that all the intervening ratings listed in Table 1 are included.

3 — Bold type - voltages listed in ANSI C84.1-1982.

4 — Italics type - voltages not listed in ANSI C84.1-1982.

Table 5—Range of Voltage and Kilovolt-Ampere Ratings for Three-Phase Transformers With Load Tap Changing 3750-10 000 kVA

High Voltage Ratings (V)	**Low-Voltage Ratings (V)**					
	2400, *2520,* **4160Y/2400,** 4360Y/2520	**4800,** *5040,* **8320Y/4800,** *8720Y/5040*	**6900,7200,** *7560,* **12 470Y/7200,** *13 090Y/7560,* **13 200Y/7620,** **13 800Y/7970**	**13 800,** **12 000,** *12 600* **13 200,** *14 400*	**24 940GrdY/14 400**	**24 940GrdY/14 400** **34 500,** **34 500GrdY/19 920,** *36 230GrdY/20 920*
	Self-Cooled (OA) Kilovolt-Ampere Ratings (kVA)					
6900,7200	3750	—	—	—	—	—
12 000,	3750-7500	—	—	—	—	—
12 470	—	—	—	—	—	—
13 200	—	—	—	—	—	—
13 800	—	—	—	—	—	—
23 000	3750-7500	3750-10 000	3750-10 000	—	—	—
34 500	3750-7500	3750-10 000	3750-10 000	3750-10 000	—	—
46 000	3750-7500	3750-10 000	3750-10 000	3750-10 000	—	—
69 000	3750-7500	3750-10 000	3750-10 000	3750-10 000	—	—
115 000	5000-7500	5000-10 000	5000-10 000	5000-10 000	5000-10 000	5000-10 000
138 000	5000-7500	5000-10 000	5000-10 000	5000-10 000	5000-10 000	5000-10 000

NOTES:

1 — All voltages are Δ unless otherwise indicated.

2 — Kilovolt-ampere ratings separated by a dash indicate that all the intervening ratings listed in Table 1 are included.

3 — Bold type - voltages listed in ANSI C84.1-1982.

4 — Italics type - voltages not listed in ANSI C84.1-1982.

Table 6—Range of Voltage and Kilovolt-Ampere Ratings for Three-Phase Transformers With, or Without, Load Tap Changing 12 000-60 000 kVA

High voltage Ratings (V)	Low-Voltage Ratings (V)				
	4800,*5040,* **8320Y/4800,** *8720Y/5040*	**6900,7200,***7560,* **12 470Y/7200,** *13 090Y/7560, 13 200 Y/7620,* **13 800Y/7970**	**12 000,***12 600,* **13 200,13 800,** *14 400*	**24 940GrdY/14 400**	**34 500, 34 500GrdY/19 920,** *36 230GrdY/20 920*
	Self-Cooled (OA) Kilovolt-Ampere Ratings (kVA)				
23 000	12 000-15 000	12 000-30 000	—	—	—
34 500	12 000-15 000	12 000-30 000	12 000-30 000	—	—
46 000	12 000-15 000	12 000-30 000	12 000-30 000	—	—
69 000	12 000-15 000	12 000-30 000	12 000-30 000	—	—
115 000	12 000-15 000	12 000-60 000	12 000-60 000	12 000-60 000	12 000-60 000
138 000	12 000-15 000	12 000-60 000	12 000-60 000	12 000-60 000	12 000-60 000
161 000	12 000-15 000	12 000-60 000	12 000-60 000	12 000-60 000	12 000-60 000
230 000	12 000-15 000	12 000-60 000	12 000-60 000	12 000-60 000	12 000-60 000

NOTES:

1 — All voltages are Δ unless otherwise indicated.

2 — Kilovolt-ampere ratings separated by a dash indicate that all the intervening ratings listed in Table 2 are included.

3 — Bold type - voltages listed in ANSI C84.1-1982.

4 — Italics type - voltages not listed in ANSI C84.1-1982.

Table 7—High-Voltage Winding Insulation Levels of Single-Phase Transformers

High-Voltage Ratings (V)	Basic Impulse Insulation Level (kV)
2400/4160Y	75
4800/8320Y	95
6900/11 950Y	110
7200/12 470Y	110
7620/13 200Y	110
12 000	110
13 200	110
13 800	110
23 000	150
34 500	200
46 000	250
69 000	350
115 000	450
138 000	550

NOTES:

1 — All voltages are Δ unless otherwise indicated.

2 — Bold type - voltages listed in ANSI C84.1-1982.

3 — Italics type - voltages not listed in ANSI C84.1-1982.

Table 8—High-Voltage Winding Insulation Levels of Three-Phase Transformers

High-Voltage Ratings (V)	Basic Impulse Insulation Level (kV)	
	Distribution Transformers	**Power Transformers**
2 400	45	60
4 160	60	75
4 800	60	75
6 900	75	95
7 200	75	95
12 000	95	110
13 200	95	110
13 800	95	110
23 000	125	150
34 500	150	200
46 000	—	250
69 000	—	350
115 000	—	450
138 000	—	550
161 000	—	650
230 000	—	750

NOTES:

1 — All voltages are Δ unless otherwise indicated.

2 — Distribution BILs only applicable to non-load-tap-changing transformers.

Table 9—Low-Voltage Winding Insulation Levels

Voltage Ratings (V)		Basic Impulse Insulation Level (kV)	
Single-Phase	**Three-Phase**	**Distribution Transformers**	**Power Transformers**
480	**480Y/277,480**	30	45
—	**2400,** *2520*	45	60
2400/4160Y, *2520/4360Y*	**4160Y/2400,** *4360 Y/2520,* **4800,** *5040*	60	75
4800/8320Y, *5040/8720Y*	**6900,7200,** *7560,* **8320Y/4800,** *87200Y/5040*	75	95
6900/11 950Y, **7200/12 470Y,** *7560/13 090 Y,* **7620/13 200Y 7970/12 800Y,12000, 12 600,13 200,** *14 400,* **13 800**	**12 000,** *12 600,* **13 200, 13 800,** *14 400,* **12 470Y/7200,** *13 090 Y/7560,* **13 200Y/7620,13 800Y/7970**	—	110
14 400/24 940Y	**24 940GrdY/14 400**	—	150
34 500	**34 500**	—	200
19 920/34 500Y	**34 500GrdY/19 920,**	—	—
20 920/36 230Y	*36 230GrdY/20 920*	—	—

NOTES:

1 — All voltages are Δ unless otherwise indicated.

2 — Distribution BILs only applicable to non-load-tap-changing transformer.

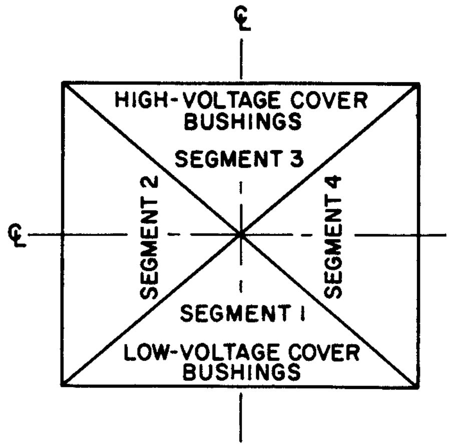
3 — Bold type - voltages listed in ANSI C84.1-1982.

4 — Italics type - voltages not listed in ANSI C84.1-1982.

Table 10—BILs and Percent Impedance Voltages at Self-Cooled (OA) Rating

	Without Load Tap Changing		With Load Tap Changing
High-Voltage BIL (kV)	**Low Voltage 480 V**	**Low Voltage 2400 V and Above**	**Low Voltage 2400 V and above**
60-110	5.75*	5.5*	-
150	6.75	6.5	7.0
200	7.25	7.0	7.5
250	7.75	7.5	8.0
350	—	8.0	8.5
450	—	8.5	9.0
550	—	9.0	9.5
650	—	9.5	10.0
750	—	10.0	10.5

*For transformers greater than 5000 kVA self-cooled, these values shall be the same as those shown for 150 kV HV BIL.



Accessories	Locations	Section
Tap-changer operating handle	S1, S4, See Ref	5.1.1
*Liquid-level indicator	S1	5.1.2
*Liquid-temperature indicator	S1	5.1.3
Drain and filter valves	S1	5.1.5
Nameplate	S1	5.4
*Pressure-vacuum gage	S1	5.1.4
Jacking facilities	See Ref	5.3.4
Ground pad(s)	See Ref	5.5
†Load-tap-changing equipment	S1 or S2	6
†Auxiliary cooling control	S1 or S2	5.9

*Not furnished for transformers with distribution BIL characteristics 200 kV and below.
†When furnished

Note: Some designs include accessories and wiring connections as part of the load-tap-changing equipment assembly. When this is the case, accessories may be located in the same segment as the load tap changer and may be viewed parallel to the segment centerline.

Figure 1—Accessories

5. Construction

5.1 Accessories

The accessories shall be as listed in Figure 1.

Accessories listed in 5.1.1 through 5.1.5 shall be included and located as shown in Figures 1 or 2.

See Table 11 for information on accessories and construction features to be provided on transformers of various sizes.

5.1.1 Tap Changer

A tap changer for de-energized operation with the operating handle brought out through the side of the tank in segment 1 or 4 at a height convenient to the transformer design, shall be provided. If for design reasons it cannot be located in segment 1 or 4, it may be located in the sidewall of one of the other segments.

The tap-changer handle shall have provision for padlocking, and shall provide visible indication of the tap position without unlocking. A hole with a minimum diameter of 9.5 mm (3/8 inch) shall be provided for the padlock.

The plate indicating tap-changer position shall be marked with letters or Arabic numerals in sequence. The letter “A” or the Arabic numeral “1” shall be assigned to the voltage rating providing the maximum ratio of transformation.

5.1.2 Liquid-Level Indicator

A magnetic level gage with vertical face shall be mounted on the side of the tank in segment I and shall be readable to a person standing at the level of the base.

The gage shall have a dark-face dial with light markings and a light-colored indicating hand. The diameter of the dial (inside bezel) shall be:

1) 82.6 mm (3-1/4 inches) ± 6.4 mm (1/4 inch) when the 25 °C liquid level is 2.44 m (96 inches) or less above the bottom of the base
2) 140 mm (5-1/2 inches) ± 12.7 mm (1/2 inch) when the 25 °C liquid level is more than 2.44 m (96 inches) above the bottom of the base.

Dial markings shall show the 25°C level and the minimum and maximum levels.

The words "Liquid Level" shall be on the dial or on a suitable nameplate adjacent thereto.

The 25°C liquid level shall also be shown by suitable permanent markings on the tank or by an indication on the nameplate of the distance from the liquid level to the highest point of the handhole or manhole flange surface.

The change in liquid level per 10°C change in temperature shall be indicated on the nameplate.

5.1.3 Liquid-Temperature Indicator

A dial-type thermometer shall be mounted on the side of the tank in segment 1.

For mounting heights 2.44 m (96 inches) or less from the bottom of the base, the face of the thermometer shall be mounted in a vertical plane: and for mounting heights greater than 2.44 m (96 inches), the face shall be at an angle of 30 degrees from the vertical.

The thermometer shall be direct-stem-mounted in a closed well at a suitable level to indicate the top-liquid temperature. For dimensions of the well, see ANSI/ IEEE C57.12.00-1987.

The thermometer shall have a dark-face dial with light markings, a light-colored indicating hand, and an orange-red maximum indicating hand, with provision for resetting. The diameter of the dial (inside bezel) shall be 114 mm (4-1/2 inches) ± 25.4 mm (1 inch). The dial markings shall cover a range of 0°C to 120°C.

The words "Liquid Temperature" shall be on the dial or on a suitable nameplate mounted adjacent to the indicator.

5.1.4 Pressure-Vacuum Gage

A pressure-vacuum gage shall be provided for transformers above 2500 kVA, or above 200 kV BIL.

The diameter of the dial (inside bezel) shall be 88.9 mm (3-1/2 inches) ± 6.4 mm (1/4 inch). The gage shall have a dark-face dial with light-colored markings and a light-colored pointer, and it shall be located either in segment I or in that half of segment 4 that is adjacent to segment 1.

The scale range for the pressure-vacuum gage shall be between 10 psi (69 kPa), positive and negative.

5.1.5 Drain and Filter Valves

A combination drain and lower filter valve shall be located on the side of the tank in segment 1. This valve shall provide for drainage of the liquid to within 25.4 mm (1 inch) of the bottom of the tank.

The drain valve shall have a built-in 9.5-mm (3/8-inch) sampling device, which shall be located in the side of the valve between the main valve seat and the pipe plug.

The sampling device shall be supplied with a 7.9-mm (5/16-inch) - 32 male thread for the user's connection and shall be equipped with a cap.

The size of the drain valve shall be 25.4 mm (1 inch) for transformers through 2500 kVA and 50.8 mm (2 inches) for the larger kilovolt-ampere ratings, and the drain valve shall have tapered pipe threads (National Pipe Thread), (in accordance with ANSI/ASME B 1.20.11983), with a pipe plug in the open end.

Transformers through 2500 kVA shall have a 25.4-mm (1-inch) upper filter plug, or cap, located above the maximum liquid level in segment 1.

Transformers above 2500 kVA shall have an upper filter valve located below the 25°C liquid level in segment 1. The size of the upper filter valve shall be 25.4 mm (1 inch), and the upper filter valve shall have 25.4-mm (1-inch) threads (in accordance with ANSI/ASME B1.20.1-1983) with a pipe plug in the open end.

5.2 Bushings

The insulation level of line bushings shall be equal to or greater than the insulation level of the windings to which they are connected.

The insulation level of the low-voltage neutral bushing on three-phase transformers having a Y-connected low-voltage winding shall be the same as that of the low-voltage line bushings for windings 15 kV and below. For windings above 15 kV, a 15-kV neutral bushing with 110-kV BIL shall be provided.

Unless otherwise specified, bushings shall be mounted on the cover and located as shown in Figure 2.

5.2.1

Electrical characteristics of outdoor transformer bushings shall be as listed in ANSI/IEEE C57.12.00-1987 for bushings with a nominal system voltage of 8.7 kV and below: or as listed in ANSI/IEEE 21-1976 and ANSI/IEEE 24-1984 for bushings with nominal system voltage of 15 kV and above.

5.2.2

Bushings for use with outdoor power transformers shall have dimensions as listed in ANSI/IEEE 21-1976 and ANSI/IEEE 24-1984.

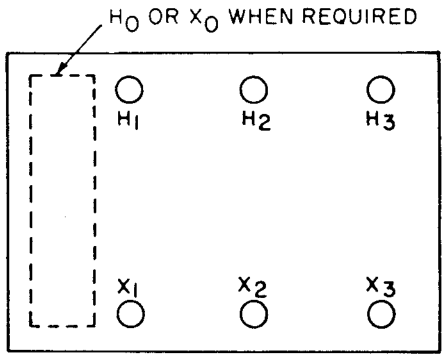
5.2.3

Four cover bushings shall be provided for each permanently connected Y-winding on three-phase transformers.

5.3 Lifting, Moving, and Jacking Facilities

5.3.1 Safety Factor

Lifting, moving, and jacking facilities shall be designed to provide a safety factor of 5. This safety factor is the ratio of the ultimate stress of the material used to the working stress. The working stress is the maximum combined stress developed in the lifting facilities by the static load of the component being lifted.



Note: For single phase transformers, omit H_3, X_3, and neutral bushings.

Figure 2—Bushing Arrangement

Table 11—"Basic Standard" Construction Features

		kVA, OA Ratings				
		Without Load Tap Changing			With Load Tap Changing	
Section	**Items**	**750–2500 DIST BILs**	**750–10 000 POWER BILs**	**12 000–60 000 POWER BILs**	**3750–10 000 POWER BILs**	**12 000–60 000 POWER BILs**
5.1	Accessories					
5.1.1	Tap-Changer	S	S	S	S	S
5.1.2	Liquid-Level Indicator	—	S	S	S	S
5.1.3	Liquid-Temperature Indicator	—	S	S	S	S
5.1.4	Pressure-Vacuum Gage	—	S	S	S	S
5.1.5	Drain and Filter Valves (or Conn)	S	S	S	S	S
5.2	Bushings	S	S	S	S	S
5.3	Lifting, Moving, and Jacking Facilities	S	S	S	S	S
5.3.4	Jacking Facilities	—	S	S	S	S
5.4	Nameplate	S	S	S	S	S
5.5	Ground Pad(s)	S	S	S	S	S
5.6	Polarity, Angular Displacement, and Terminal Markings	S	S	S	S	S
5.7.1	Oil Preservation	S	S	S	S	S
5.7.2	Pressure-Vacuum Bleeder	—	S	S	S	S
5.8	Tanks	S	S	S	S	S
5.9	Auxiliary Cooling Equipment	A	A	A	A	A
5.9.1	Controls for Auxil iary Cooling Equipment	A	A	A	A	A

Table 11—"Basic Standard" Construction Features (Continued)

		kVA, OA Ratings				
		Without Load Tap Changing			With Load Tap Changing	
Section	Items	750–2500 DIST BILs	750–10 000 POWER BILs	12 000–60 000 POWER BILs	3750–10 000 POWER BILs	12 000–60 000 POWER BILs
5.9.2	Fans	A	A	A	A	A
5.9.3	Pumps	—	—	A	—	A
5.10	Auxiliary Equipment Power Supply	—	A	A	A	A
6	Load-Tap-Changing Equipment	—	—	—	S	S
6.1	Load Tap Changer	—	—	—	S	S
6.2	Arcing Tap Switch	—	—	—	S	S
6.3	Motor-Drive Mechanism	—	—	—	S	S
6.4	Position Indicator	—	—	—	S	S
6.5	Operation Counter	—	—	—	S	S
6.6	Automatic Control Equipment	—	—	—	S	S

"S" indicates "standard"

"A" indicates "available when specified"

5.3.2 Lifting Facilities

Lifting facilities shall be provided for lifting the cover separately and, also, for lifting the core and coil assembly from the tank using four lifting cables.

Facilities for lifting the complete transformer (with the cover securely fastened in place) shall be provided. Lifting facilities shall be designed for lifting with four vertical slings. (For large transformers the use of spreaders or a lifting beam may be involved.) The bearing surfaces of the lifting facilities shall be free from sharp edges and shall be provided with a hole having a minimum diameter of 20.6 mm (13/16 inch) for guying purposes.

5.3.3 Moving Facilities

The base of the transformer shall be of heavy plate or have members forming a rectangle that will permit rolling or skidding in the directions of the centerlines of the segments.

The points of support shall be so located that the center of gravity of the transformer as prepared for shipment will not fall outside these points of support when the base is tilted 15 degrees or less from the horizontal, with or without oil in the transformer.

Provision shall be made on or adjacent to the base for pulling the transformer parallel to the centerline of segments 1 and 3, and to the centerline of segments 2 and 4.

The base shall be constructed so that the external edges on all four sides are rounded or slope upward at an angle of approximately 45 degrees.

5.3.4 Jacking Facilities

Jacking facilities shall be located near the extreme ends of the junctions of the segments.

For transformers above 2500 kVA, dimensions and clearances for jacking provisions shall be as shown in Figure 3.

5.4 Nameplate

The nameplate shall conform to the requirements of nameplate C as described in ANSI/ IEEE C57.12.00-1987. It shall be located in segment 1 near the centerline and near eye level. It may be located in segment 2 when load-tap-changing equipment is located in segment 2.

For load-tap-changing transformers, the words “load-tap-changing transformer” shall be used instead of the word “transformer.”

Voltage and current ratings shall be given as follows:

0 to	99.9	to nearest 0.1
100 to	999	to nearest 1
1 000 to	9 999	to nearest 5
10 000 to	99 999	to nearest 10
100 000 and greater		to nearest 25

5.5 Ground Pads

5.5.1

A tank-grounding pad shall consist of a copper-faced steel pad or a stainless-steel pad without copper facing, 2 inches × 3-1/2 inches (50.8 mm × 88.9 mm), with two holes horizontally spaced on 44.5-mm (1-3/4-inch) centers and drilled and tapped for 12.7-mm (1/2-inch) - 13 Unified National Coarse thread (UNC) (as defined in ANSI B1.1-1982). Minimum thickness of the copper facing shall be 0.4 mm (0.015 inch). Minimum threaded depth of the holes shall be 12.7 mm (1/2 inch). Thread protection for the ground pad shall be provided.

The ground pad shall be welded on the base or on the tank wall near the base. If the base is detachable, the ground pad shall be located on the tank wall.

5.5.2

Transformers 2500 kVA and smaller shall be provided with one ground pad available for connection to a neutral (if present) or near the low-voltage (LV) bushings.

5.5.3

Transformers larger than 2500 kVA shall have one ground pad located toward the extreme left of segment 1 and another diagonally opposite in segment 3, located in such a way as not to interfere with the jacking facilities.

5.6 Polarity, Angular Displacement, and Terminal Markings

5.6.1 Polarity

All single-phase transformers shall have subtractive polarity.

5.6.2 Angular Displacement

The angular displacement between high-voltage and low-voltage terminal voltages of three-phase transformers with Δ–Δ connections shall be 0 degrees.

The angular displacement between high-voltage and low-voltage terminal voltages of three-phase transformers with Y–Δ or Δ–Y connections shall be 30 degrees, with the low voltage lagging the high voltage as shown in Figure 4.

Phasor relations shah be as shown in Figure 4.

5.6.3 Terminal Markings

External terminals shah be marked in accordance with ANSI C57.12.70-1978. The high-voltage and low-voltage bushing arrangements shah be as shown in Figure 2.

5.7 Liquid Preservation

5.7.1 Sealed-Tank System

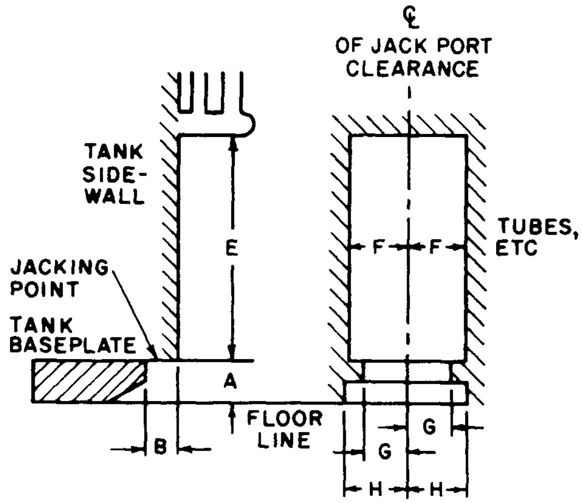
A sealed-tank system shall be provided.

NOTE — A sealed-tank system is one in which (1) the interior of the transformer will be sealed from the atmosphere throughout a top liquid temperature range of 100°C and (2) the gas plus liquid volume will remain constant so that the internal gas pressure will not exceed 10 psi (69 kPa) gage positive or 8 psi (55.2 kPa) gage negative.

5.7.2 Pressure-Vacuum Bleeder

A pressure-vacuum bleeder device set to operate at the maximum operating pressures (positive and negative) indicated on the nameplate shall be furnished on transformers 2500 kVA and larger with power transformer BILs.

A pressure-vacuum bleeder device shall not be furnished on transformers 2500 kVA and smaller with distribution transformer BILs.



Weight 35,000 lb (15,900 kg) or Less			Weight 35,000–65,000 lb (15,900–29,500 kg)			Weight over 65,000 lb (29,500 kg)		
A	88.9 mm	3-1/2 in	A	127 mm	5 in	A	457 mm	18 in
B	63.5 mm	2-1/2 in	B	63.5 mm	2-1/2 in	B	102 mm	4 in
E	686 mm	27 in	E	686 mm	27 in	E	508 mm	20 in
F	127 mm	5 in	F	127 mm	5 in	F	127 mm	5 in
G	76.2 mm	3 in	G	76.2 mm	3 in	G	76.2 mm	3 in
H	127 mm	5 in	H	127 mm	5 in	H	127 mm	5 in

Notes:

(1) Dimensions E, F, G, and H are free clearances.
(2) Where required in manufacturer's standard designs, any dimensions may be in excess of those shown.
(3) E applies to nonremovable coolers only.
(4) Weight includes completely assembled transformer and fluid.

Figure 3—Provision for Jacking (Transformers above 2500 kVA)

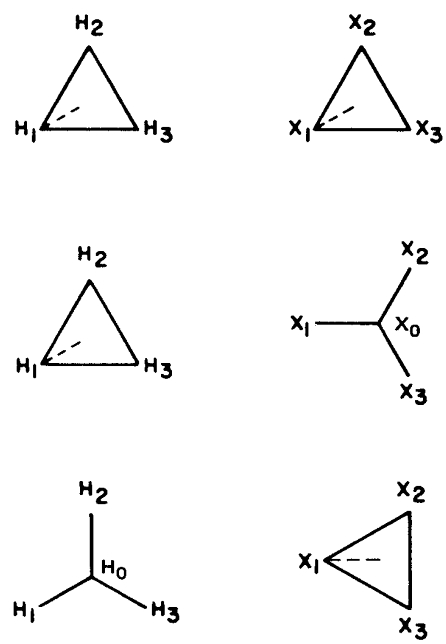


Figure 4—Angular Displacement

5.8 Tanks

5.8.1

Maximum operating pressures (positive and negative) for which the transformer is designed shall be indicated on the nameplate. The completely assembled transformers shall be designed to withstand, without permanent deformation, a pressure 25 percent greater than the maximum operating pressure.

5.8.2

Tanks shall be designed for vacuum filling (external pressure of one atmosphere, essentially full vacuum) in the field (1) on all transformers with high-voltage insulation levels of 350 kV BIL and above and (2) on all transformers rated 10 000 kVA and above, regardless of BIL.

5.8.3

A welded main cover shall be provided. Hand-holes or manholes shall be provided in the cover. Hand-holes, if circular, shall be a minimum of 9 inches (229 ram) in diameter. If rectangular, they shall be at least 114 mm (4-1/2 inches) wide and shall have an area of at least 41 900 mm^2 (65 square inches). Manholes, if circular, shall be a minimum of 381 mm (15 inches) in diameter. If rectangular or oval, they shall have minimum dimensions of 254 mm × 406 mm (10 inches × 16 inches).

A pressure-relief device shall be provided on the cover for transformers above 2500 kVA or above 200 kV BIL.

5.8.4

In load-tap-changing transformers, if the arcing tap switch has components that involve direct arcing in liquid, these components shall be located in a compartment sealed in such a way as to prevent transfer of liquid to any other compartment or to the main tank.

5.9 Auxiliary Cooling Equipment

5.9.1 Control of Auxiliary Cooling Equipment

5.9.1.1

The equipment for automatic control of auxiliary cooling equipment controlled from the top-liquid temperature shall consist of:

1) A thermally operated control device with the thermal element mounted in a well and responsive to the top-liquid temperature of the transformer;
2) A manually operable switch connected in parallel with the automatic control contacts and enclosed in a weatherproof cabinet located on the side of the tank of segment 1, at a height not greater than 1.52 m (60 inches) above the base.

5.9.1.2

When specified, or for transformers with forced-cooled ratings of 133 percent or greater of the self-cooled (OA) rating, the equipment for automatic control of auxiliary cooling equipment for transformers controlled from the winding temperature shall consist of:

1) A winding-temperature simulator device with a thermal element mounted in a well and responsive to the simulated winding hottest spot temperature of the transformer.

The winding-temperature simulator shall be a dial-type instrument and shall be mounted on the side of the tank in segment 1. For mounting heights of 2.44 m (96 inches) or less from the bottom of the base, the face of the instrument shall be mounted in a vertical plane. For mounting heights greater than 2.44 m (96 inches), the face shall be at an angle of 30 degrees from the vertical.
The instrument shall be direct-stem-mounted in a closed well at a suitable level. The dimensions of the well shall be as specified in ANSI/IEEE C57.12.00-1987.
The instrument shall have a dark-face dial with light markings, a light-colored indicating hand, and an orange-red maximum indicating hand, with provision for resetting. The diameter of the dial (inside bezel) shall be 114 mm (4-1/2 inches) ± 25.4 mm. The dial markings shall cover a range of 0°C to 180°C.
The words "Winding Temperature" shall be on the dial or on a suitable nameplate mounted adjacent to the simulator.
The simulator shall have three sets of alarm contacts in accordance with 7.1, and with factory temperature settings as follows:

Contact	Function
1	Supply power to first-bank cooling
2	Supply power to second-bank cooling
3	Initiate alarm or actuate relay

2) A manually operable switch connected in parallel with the automatic control contacts and enclosed in a weather-resistant cabinet located on the side of the tank in segment 1, at a height not greater than 1.52 m (60 inches) above the base.
A switch for automatic and manual control.
A relay for control shall be mounted on the side of the transformer in segment 1.

5.9.2 Fans

Fan motors shall be 240 volts, 60 Hz, single phase, without centrifugal switch, and shall be individually fused or otherwise thermally protected.

If the power supply for 240-volt single-phase motors is not available, provision shall be made to accommodate another single-phase motor supply voltage in accordance with ANSI C84.1-1982 , not in excess of 600 volts.

NOTE — See 9.9 for provision for future fans.

5.9.3 Pumps

Pump motors shall be 240 volts, 60 Hz. single phase, without centrifugal switch, and shall be individually fused or otherwise thermally protected.

Pump facilities shall include valves to allow removal of the pump with minimum loss of insulating oil.

5.10 Power Supply for Transformer Auxiliary Equipment and Controls

The power supply voltage for the transformer auxiliary equipment and controls should be specified and provided by the user. It should be in accordance with ANSI C84.1-1982.

The voltage rating for auxiliary equipment and controls supplied with the transformer should also be in accordance with ANSI C84.1-1982.

6. Basic Construction Features — Load-Tap-Changing Equipment

6.1 Load-Tap-Changing Equipment

The load-tap-changing equipment shall consist of a liquid-immersed arcing tap switch or a tap selector and an arcing switch, a motor mechanism, and automatic control devices located in segment 1 or 2.

6.2 Arcing Tap Switch

The arcing switch, or tap selector and arcing switch, shall have the following features:

1) Components of the arcing tap switch that involve direct arcing in liquid shall be located in one or more liquid-filled compartments with a removable bolted cover, or covers, for access to such components without opening the main tank or lowering the liquid in the main tank. Covers weighing more than 20.4 kg (45 pounds) shall be hinged and removable. Covers weighing 20.4 kg (45 pounds) or less shall have handles. Provision shall be made for the escape of gas produced by the arcing.
2) A drain valve of the ball type shall be located in the bottom of each oil-filled compartment to provide complete off drainage. The size of the drain valve shall be 25.4 mm (1 inch), and the drain valve shall have 25.4-mm (1-inch) tapered pipe threads (National Pipe Thread) in accordance with ANSI/ASME B1.20.1-1983, with a pipe plug in the open end. The drain valve shall have a built-in 9.5-mm (3/8-inch) sampling device, which shall be located on the side of the valve between the main valve seat and the pipe plug. The device shall be supplied with a 7.9.mm-1.3 (5/16-inch-32)male thread for the user's connection and shall be equipped with a cap. A 25.4-mm (1-inch) filling plug shall be located in the top of each oil-filled compartment.
3) A magnetic liquid-level gage with a vertical face shall be mounted on the side of each oil-filled compartment. For details see 5.1.2.

6.3 Motor-Drive Mechanism

The motor-drive mechanism shall have the following features:

1) A single-phase, 60-Hz motor without centrifugal switch suitable for operation from a 240/120-volt, three-wire source.

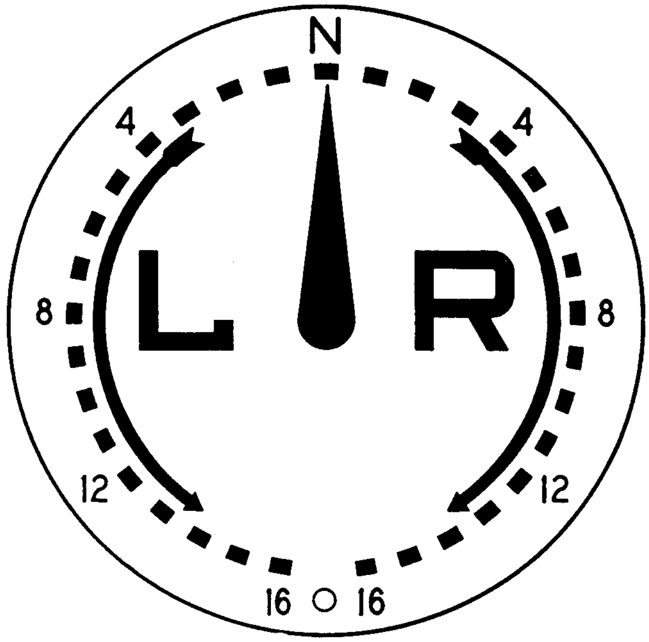
   NOTE — The power source for the motor drive and for operating forced-air-cooling fans (when fans are included) shall be 240/ 120 volts, three wire, single phase, 60 Hz, with maximum voltage to ground not to exceed 150 volts. This power source shall be provided by the user and shall be separate from the transformer.
2) A hand crank or spoke-type handwheel for manual operation of the driving mechanism shall be provided. The hand crank or spoke-type handwheel shall be electrically interlocked to prevent operation by the motor while the crank or spoke-type handwheel is engaged. A place for storing the hand crank or spoke-type handwheel, if detachable, shall be provided.

   NOTE — The manual handcrank operation is not designed to be suitable for operation of the load tap changer under load.
3) Mechanically operated electric limit switches and mechanical stops shall be provided on the drive mechanism to prevent overtravel beyond the maximum raise and lower positions.

6.4 Position Indicator

A position indicator for the load tap changer with maximum and minimum indicating hands and provision for resetting for a person standing at the base of the transformer shall be provided. The indicator shall be readable from the base of the transformer and shall be so located that it can be read while the load tap changer is operated by hand. The position indicator shall be marked in accordance with the following:

1) The normal (rated low-voltage) position shall be located on the vertical centerline of the dial, preferably at the top of the dial, and shall be indicated by the letter "N."
2) The raise range, when referred to the regulated (low-voltage) circuit, shall be located on the right-hand portion of the dial. A large letter "R" (Raise), appearing only once, shall be located in the right-hand half with an arrow indicating the direction of raise. The sixteen tap positions in the raise range shall be marked, and a number shall appear opposite at least every fourth position. Number 16 shall be the highest voltage position (see Figure 5).
3) The lower range, when referred to the regulated (low-voltage) circuit, shall be located on the left-hand portion of the dial. A large letter "L" (Lower), appearing only once, shall be located in the left-hand half with an arrow indicating the direction of lower. The sixteen tap positions in the lower range shall be marked, and a number shall appear opposite at least every fourth position. Number 16 shall be the lowest voltage position (see Figure 5).



Note: This figure is intended to present a schematic rather than a pictorial illustration of the dial face. For detailed specifications, see 6.4

Figure 5—Position Indicator for Load Tap Changer

6.5 Control Equipment and Accessories

Control devices to facilitate manual and automatic control of the load-tap-changing equipment shall be provided.

6.5.1 Enclosure

A weather-resistant cabinet shall be provided for housing the automatic control and related devices. The cabinet shall be equipped with breather, hinged doors, and provision for entrance of up to three 38.1-mm (1-1/2-inch) conduits in the bottom. The doors shall provide access to the control and accessory devices and shall have provision for padlocking consisting of matching holes having a minimum diameter of 9.5 mm (3/8 inch).

6.5.2 Devices and Accessories

The following devices and accessories shall be mounted in the cabinet:

6.5.2.1

Automatic control equipment including:

1) A voltage-sensing device with provision for voltage level and bandwidth adjustment.
   Voltage setting range shall be from at least 108 volts to 132 volts. The difference between the actual bandwidth center voltage and the marked value at any setting over the range shall not exceed 1 percent.
   Total bandwidth setting range shall be from at least 1.5 volts to 3.0 volts. The difference between the actual bandwidth voltage and the marked value shall not exceed ±10 percent of the marked value set.
2) A device suitable for providing a time delay in the range from at least 15 seconds to 90 seconds in both the raise and lower directions. (The time delay applies only to the first required change, if more than one change is required to bring the voltage within the bandwidth setting.) The difference between the actual time delay and the marked value at any setting shall not exceed ±20 percent when initiated with no stored delay in an integrating-type circuit.
3) A line-drop compensator to permit compensation for the line drop caused by load-current fluctuations.
   Line-drop compensation adjustment shall be in the range of at least 24 volts at any phase angle except the fourth quadrant (-R, -X). Where independent R and X controls are provided, each shall have a maximum setting of at least 24 volts. The difference between the actual compensation voltage and the marked value of any setting of either the resistance or the reactance element of the compensator, expressed as a percentage of 120 volts, shall not exceed one percent with rated current flowing through the compensator.
4) Switching to provide for automatic operation and for nonautomatic raise-lower operation with intermediate off positions.
5) Terminals for reading the voltage supplied to the automatic control equipment by the voltage source.
6) Provision for isolating facilities that permit the application of a test voltage to adjust the voltage level and bandwidth.
7) Provision for insertion of a circulating current input to provide for parallel operation by the circulating current method. This isolated current input shall essentially duplicate the reactance input of the line-drop compensator with its control set on 24 volts. The sensitivity need not be adjustable.
   This input shall provide a voltage that adds vectorially with the voltage placed on the control device voltage sensing input. With a current of 0.1 amperes, in phase with the voltage input, passing into the paralleling input, the voltage that adds to the voltage input shall be shifted 90 degrees. With this same current rotated 90 degrees, the sensitivity of the voltage setpoint should change 12 volts ± 20 percent.

6.5.2.2

An operation counter to register the accumulated number of tap-changer operations performed.

6.5.2.3

Protective devices consisting of:

1) Overcurrent automatic-trip temperature-compensated air circuit breaker with manual reset, for control of the voltage circuit to the control devices
2) Overcurrent automatic-trip temperature-compensated air circuit breaker with manual reset, for control of the power circuit to the control devices

6.5.2.4

A screw-base lamp socket with a switch and a convenience outlet for a 120-volt, single-phase 60-Hz supply.

6.5.2.5

A heater with a manual switch.

6.5.3 Parallel Operation

Space shall be provided for mounting the equipment required for parallel operation by the circulating-current method.

6.5.4 Transformers

The manufacturer shall furnish current transformers, and the user shall furnish a voltage transformer for the supply of power to the control circuit. The current transformer or transformers shall deliver not less than 0.15 ampere and not more than 0.20 ampere to the circuits of the paralleling equipment when the power transformer is operating at the maximum continuous rating for which it is designed, including increases that can be obtained by normal cool cooling modifications.

The current transformers shall deliver to the line-drop compensator a current that is in phase with the line-drop compensator's voltage supply at unity power factor.

For Y-connected windings the current transformers shall be suitable for use with the line-drop compensator's voltage supply that is connected line to neutral, X_1-X_o (Figure 4).

For A-connected windings the current transformers shall be suitable for use with a line-drop compensator's voltage supply that is connected line to line, X_1-X_2.

6.6 Automatic Control Equipment Operating Requirements

6.6.1 Environment

The operating temperature of the control equipment may range from –30°C to +65°C. The humidity may range from zero to 100 percent relative humidity. The altitude may range up to 9900 feet (3000 m).

6.6.2 Accuracy, Burden, and Response Time

6.6.2.1 Accuracy and Burden

The automatic control equipment shall have an overall accuracy within ±1 percent when used with a voltage source that shall be provided by the user and that is external to the transformer. This voltage source shall be 0.3 accuracy class with a total operating burden that shall include a voltage-sensing device and all other devices connected thereto in accordance with ANSI C57.13-1978. The burden imposed on the voltage source by the automatic load-tap-changer control equipment shall not exceed 60 volt-amperes.

6.6.2.2 Response Time

A step change in applied voltage of 0.75 volt from outside the band to within the band shall cancel any raise or lower signal within 0.3 second.

6.6.3 Accuracy Considerations

The accuracy with which control devices of a load-tap-changing transformer can maintain desired voltage is dependent upon a number of varying factors, principal among which are variations in ambient temperatures, frequency, transformer load, and tap-changer position.

Accuracy is affected in varying degrees by the effects of each of these variations on the individual parts of the control.

For determining the accuracy of a load-tap-changing control, only the combination of control parts and varying factors that significantly affect the accuracy are included.

For determining the accuracy of the control, the percent error is based on the following reference conditions: ambient temperature of 25°C, rated frequency, tap changer on neutral and delivering rated output voltage, zero load current except that line-drop compensation errors are based on rated current (0.2 ampere).

Each individual error is stated in terms of its effect on the response of the control. Errors causing the control to hold an output voltage higher than the reference value are "plus errors." Errors causing the control to hold the output voltage level lower than the reference values are "minus errors."

The effect of each principal varying factor is considered separately with the values of the other factors held constant. The overall error for determining the accuracy is obtained by taking the sum of the selected individual errors, each determined independently. For this purpose errors relate to the divergence of this sum from the voltage level setting, with the voltage bandwidth presumed to be zero.

Neither the sum of the positive, nor the sum of the negative errors, of the following errors to be used in accuracy determination may exceed 0.7 percent:

1) Error of the control due to variations in control operating temperature from –30°C to +65°C.
2) Error of the control due to frequency variation of ±0.25 percent from the rated frequency of the equipment.
3) With the reactance compensation set to zero and with 100 percent in-phase load current, the error in magnitude of the resistive component is defined as the difference between the actual rise of output voltage and the 12-volt expected rise as the resistance compensation is moved from zero to +12 volts.
4) With the reactance compensation set to zero and with 100 percent load current at 90-degree lagging, the phase error of resistance compensation is defined as the difference between the actual rise of output voltage and the 0.6-volt expected rise as the resistance compensation is moved from zero to +12 volts.
5) With the resistance compensation set to zero and with 100 percent in-phase load current, the error in phase angle of reactance compensation is defined as the difference between the actual rise of output voltage and the 0.6-volt expected rise as the reactance compensation is moved from zero to + 12 volts.
6) With the resistance compensation set to zero and with 100 percent load current at 90-degree lagging, the magnitude error of reactance compensation is defined as the difference between the actual rise of output voltage and the 12-volt expected rise as the reactance compensation is moved from zero to 12 volts lagging.

6.6.4 Determination of Accuracy of Control Devices by Test

This section outlines procedures for determining values of the errors upon which the accuracy of control devices as defined in this standard is based. Accuracy tests are design tests, but they are not made on every unit. The accuracy defined in this standard shall be maintained within specified limits by quality control tests.

The voltage or current applied for tests shall have a constant wave form, preferably sinusoidal in shape, with a distortion factor not exceeding 0.03 as defined in ANSI/IEEE 100-1984.

6.6.4.1 Tests for Errors in Voltage

The control device shall be set for a voltage level of 120 volts, at rated frequency and an ambient temperature of approximately 25°C, with zero current in the primary of the current supply.

The control shall be energized for at least one hour before making the first reading and should remain continuously energized throughout the test.

If the control is of an electromechanical design, and if a mechanical support is provided for the voltage sensitive element, the mechanical support should not be removed until after the relay is energized, and the mechanical support should be replaced before the relay is deenergized.

Errors shall be determined by subtracting the voltage level for reference conditions from the voltage levels for test conditions and expressing the difference in a percentage of 120 volts.

6.6.4.2 Tests for Temperature Error

These tests shall be made at rated frequency with the line-drop compensator set at zero. The frequency shall be held constant within plus or minus 0.1 percent of the rated value.

The temperature range to which the control equipment shall be subjected shall be that of the interior of the control equipment enclosure, which corresponds to an ambient temperature range of minus 30°C to plus 40°C. That is, the control shall have a temperature range from minus 30°C to plus 65°C for full accuracy, with the ability to withstand enclosure temperature of 80°C without loss of control, and with accuracy no worse than double the stated number.

Measurements of accuracy of the relay should be made at temperatures not more than 200°C apart throughout the required temperature range.

During the tests, the air temperature surrounding the control device shall be held constant and uniform within plus or minus 1 C of each of the temperatures at which the measurements are made. Each temperature should be maintained constant for a sufficient time (at least one hour) for the control device to reach thermal equilibrium before taking a test reading.

6.6.4.3 Tests for Frequency Error in Voltage Control Device

These tests shall be made at a constant ambient temperature of approximately 25°C, with the line-drop compensator set at zero. Measurements of voltage level should be taken over a sufficient range of frequencies to accurately determine the error over the specified range of rated frequency, plus or minus 0.25 percent.

6.6.4.4 Tests for Errors in Line-Drop Compensation

The auxiliary current transformer and the line-drop compensator may be tested in combination, or they may be tested separately and the combined accuracy determined by calculation or tests for the conditions outlined in 6.6.4.5 for tests in combination.

The combined accuracy may be determined by testing the compensator with current transformers having either (1) the same phase angles and available ratios as those with which it is used, or (2) the extreme phase angles and changes in ratios permitted by production tests for the current supply design, which are combined to produce maximum error.

Tests shall be made at the constant frequency of approximately rated value and a constant ambient temperature of approximately 25°C.

For convenience in testing, primary ampere-turns equivalent in magnitude and phase angle may be substituted for actual primary ampere-turns in the current transformers.

The setting and precautions outlined in 6.6.4.1 for the control device should be observed when testing the current supply and compensator in combination.

When the current supply is tested separately, ratio and phase angle tests shall be conducted in accordance with ANSI C57.13-1978.

Where in 6.6.3 and 6.6.4.5 reference is made to unity power factor and zero power factor it is presumed that these values will be attained as closely as facilities permit. Errors not exceeding 3 degrees are permitted but must be considered when calculating the theoretically correct result.

6.6.4.5 Test Procedure

1) Voltage level setting shall be set at 120 volts. Line-drop compensation voltage resistance and reactance elements shall be set to zero volts. The voltage level required to balance the control device is measured with zero current in the primary of the current supply.
2) The resistance element of the compensator shall be set at the position marked at 50 percent of the full voltage range (12 volts on a 24-volt compensator), and the reactance element shall be set at zero.
3) A test shall be made holding 100 percent of rated current in the primary of the current supply (or equivalent) at 1.0 power factor and at 0.0 power factor lagging with respect to the potential test terminal's output voltage. The actual change in voltage level from zero primary current to 100 percent primary current shall be determined.
4) The theoretically correct voltage levels at 100 percent primary current shall be computed in accordance with 6.6.4.5(6).
5) The reactance element of the compensator shall be set on the position marked as 50 percent of the full voltage range (12 volts on a 24-volt compensator) and the resistance element shall be set at zero. Steps 3 and 4 above shall be repeated.
6) The theoretically correct voltage level shall be calculated as:

$$V_1 = [V_0^2 + V_r^2 + V_x^2 - 2 \times V_0 \times (V_r^2 + V_x^2)^{0.5} \times \cos(180 - \infty + \phi)]^{0.5}$$

where:

V_1= theoretically correct voltage level with 1.0 per unit current in primary of the current supply
V_0= voltage level with zero primary current (= 120 volts)
V_r= calibrated value in volts of the resistance element for 1.0 per unit primary current
V_x= calibrated value in volts of the reactance element for 1.0 per unit primary current

$$\infty = \tan^{-1}\frac{V_x}{V_r}$$

$$\phi = \cos^{-1}(\text{power factor})$$

6.6.5 Test for Surge Withstand Capability

The automatic control equipment shall be capable of passing the surge withstand capability test specified in ANSI/IEEE C37.90.1-1974.

7. Alarm Contacts

Nongrounded alarm contacts shall be suitable for interrupting:

1) 0.02-ampere direct-current inductive load
2) 0.20-ampere direct-current noninductive load
3) 2.5-ampere alternating-current noninductive or inductive load
4) 250 volts maximum in all classes

Part B. “Other” Requirements That May Be Specified for Some Applications

(See Part A for “Basic Standard” Electrical and Mechanical Requirements)

NOTE — Certain specified applications have transformer requirements not covered in Part A. Part B comprises descriptions of the most frequently used requirements for such transformers. They shall be provided only when specified in conjunction with Part A requirements.

8. Other Ratings

8.1 Other Kilovolt-Ampere Ratings

When specified, forced-air-cooled (FA) kilovolt-ampere ratings for single- and three-phase transformers shall be as shown in Table 12 for 10 000 kVA and smaller and in Table 13 for 12 000 kVA and larger.

Table 12—Single- and Three-Phase, Self-Cooled (OA) and Forced-Air-Cooled (FA) Ratings, 750–12 500 kVA

Single-Phase (kVA)		Three-Phase (kVA) Without Load Tap Changing		Three-Phase (kVA) With Load Tap Changing	
OA	FA	OA	FA	OA	FA
833	958	750	862	—	—
1 250	1 437	1 000	1 150	—	—
1 667	1 917	1 500	1 725	—	—
2 500	3 125	2 000	2 300	—	—
3 333	4 167	2 500	3 125	—	—
5 000	6 250	3 750	4 687	3 750	4 687
6 667	8 333	5 000	6 250	5 000	6 250
8 333	10 417	7 500	9 375	7 500	9 375
—	—	10 000	12 500	10 000	12 500

Table 13—Other (Nonpreferred) Three-Phase, Self-Cooled (OA), Forced-Cooled First-Stage, and Forced-Cooled Second-Stage Kilovolt-Ampere Ratings (With, or Without, Load Tap Changing)

OA	First-Stage	Second-Stage
18 000	24 000	30 000
21 000	28 000	35 000
24 000	32 000	40 000
27 000	36 000	45 000
40 000	53 333	66 667
45 000	60 000	75 000

8.2 Other High-Voltage Ratings

When specified, high-voltage ratings for single- and three-phase transformers may be selected from the range of other high-voltage ratings listed in Tables 14 and 15. These are rated high voltages (line-to-line) and are alternates to the high-voltage ratings given in Tables 3 through 6.

The rated voltage shall be the mid-tap voltage, and all performance characteristics shall be based on the rated voltage.

Four rated kilovolt-ampere equally spaced voltage taps, two above rated voltage and two below rated voltage, shall be provided for high voltages selected from Tables 14 and 15. The total tap voltage range shall not exceed 10 percent.

The percent tap range shall be calculated as follows:

$$\text{Percent tap range} = \frac{(\text{maximum tap voltage} - \text{minimum tap voltage})100}{\text{rated tap voltage}}$$

8.3 Other Winding Ratings and Connections

When specified, any of the other winding ratings and connections listed in 8.3.1 and 8.3.2 shall be provided.

8.3.1 Y-Connected Three-Phase High-Voltage Windings

1) Three-phase transformers with Y-connected high-voltage windings should have the low-voltage windings Δ–connected and be used at a line-to-line voltage corresponding to the insulation levels shown in Tables 14 and 15. Neutral insulation levels may be as covered in ANSI/IEEE C57.12.00-1987.
2) Y-connected high voltage windings may be used on three-phase transformers, provided that the low-voltage winding is permanently A-connected, for the ratings described in Tables 14 and 15.

8.3.2 Series-Multiple Low-Voltage Ratings

Series-multiple low-voltage ratings for the voltage and kilovolt-ampere ratings are listed in Tables 16 and 17.

Transformers designed with series-multiple low-voltage ratings shall be shipped with the low-voltage windings connected for multiple operation, unless otherwise specified.

8.4 Other Basic Impulse Insulation Levels (BILs) and Impedance Voltages

When specified, other BILs and associated impedance voltages shall be provided, as shown in Table 18.

Table 14—Range of Other High-Voltage Ratings for Single- and Three-Phase Transformers, 95-650 kV BIL (Applicable to 750-10 000 kVA, OA Rating)

Basic Impulse Insulation Level (kV)	High-Voltage Ratings from Tables 2 and 3 (V)		Range of Other High-voltage Ratings, Line to Line (V)
	Single-Phase	Three-Phase	
95	**4800/8320Y**	**6 900,7200**	**6 600– 8 750**
110	*6900/11 950Y,*	**12 000,**	**11 000– 14 750**
	7200/12 470Y,	**13 200,**	
	7620/13 200Y,	**13 800,**	
	12 000,13 200,13 800		
150	**23 000**	**23 000**	**16 400– 24 600**
200	**34 500**	**34 500**	**25 700– 36 200**
250	**46 000**	**46 000**	**37 800– 46 000**
350	**69 000**	**69 000**	**56 700–121 000**
450	**115 000**	**115 000**	**110 000–145 000**
550	**138 000**	**138 000**	**132 000–145 000**
650	—	—	**132 000–145 000**

NOTES:

1 — All voltages are Δ unless otherwise indicated.

2 — Voltages separated by a dash indicate that all intervening voltages are included. Voltages separated by a comma indicate that only those listed are included.

3 — Bold type - voltages listed in ANSI C84.1-1982.

4 — Italics type - voltages not listed in ANSI C84.1-1982.

Table 15—Range of Other High-Voltage Ratings for Three-Phase Transformers, 150-900 kV BIL (Applicable to 12 000–60 000 kVA, OA Rating)

Basic Impulse Insulation Level (kV)	High-Voltage Ratings (V)	Range of Other High-Voltage Ratings, Line to Line (V)
150	**23 000**	*16 400- 24 600*
200	**34 500**	*25 700- 36 200*
250	**46 000**	*37 800- 46 000*
350	**69 000**	*56 700-121 000*
450	**115 000**	*110 000-145 000*
550	**138 000**	*132 000-169 000*
650	**161 000**	*153 000-242 000*
750	**230 000**	*153 000-242 000*
825	—	*219 000-242 000*
900	—	*219 000-242 000*

NOTES:

1 — All voltages are Δ unless otherwise indicated.

2 — Voltages separated by a dash indicate that all intervening voltages are included.

Table 16—High-Voltage and Kilovolt-Ampere Ratings for Series-Multiple Low-Voltage Ratings for Single-Phase Transformers

Series-Multiple Low-Voltage Ratings (V)	Basic Impulse Insulation Level (kV)		High-Voltage Ratings (V)			
	Multiple Connection	Series Connection	*6900/11 950Y,* **7200/12 470Y** **7620/13 200Y** **12 200,13 200,** **13 800,23 000,** **34 500,46 000,** **69 000**	**23 000** **34 500** **46 000** **69 000**	**34 500** **46 000** **69 000**	**115 000** **138 000**
			Kilovolt-Ampere Ratings (kVA)			
2400/4160Y × 4800/8320Y, *2520/4360Y × 5040/8720Y*	75	95	833-2500	-	-	-
2400/4160Y × 7200/12 470Y, *2520/4360Y × 7560/13 090Y*	75	110	-	833-2500	-	-
7200/12 470Y × 14 400	110	110	-	-	833-3333	2500-8333

NOTES:

1 — All voltages are a unless otherwise indicated.

2 — Kilovolt-ampere ratings separated by a dash indicate that all the intervening ratings listed in Table 1 are included.

3 — Bold type - voltages listed in ANSI C84.1-1982.

4 — Italics type - voltages not listed in ANSI C84.1-1982.

Table 17—High-Voltage and Kilovolt-Ampere Ratings for Series-Multiple Low-Voltage Ratings for Three-Phase Transformers

Series-Multiple Low-Voltage Ratings (V)	Basic Impulse Insulation Level (kV)		High-Voltage Ratings (V)				
	Multiple Connection	Series Connection	23 000	34 500	46 000 69 000	115 000, 138 000	34 500 46 000 69 000 115 000 138 000 161 000 230 000
			Kilovolt-Ampere Ratings (kVA)				
2400 × 4800, *2520 × 5040*	60	75	1000-7500	1000-7500	1500-7500	5000-7500	
2400 × 7200, *2520 × 7560*	60	95	-	1000-7500	1500-7500	5000-7500	-
4160Y/2400 × 8320Y/4800, *4360Y/2520 × 8720Y/5040*	75	95	1000-7500	1000-7500	1500-7500	5000-10 000	-
4160Y/2400 × 12 470Y/7200, *4360Y/2520 × 13 090Y/7560*	75	110	-	1000-7500	1500-7500	5000-10 000	-
7200 x **14 400**	95	110	-	1000-10 000	1500-10 000	5000-10 000	12 000-30 000

NOTES:

1 — All voltages are Δ unless otherwise indicated.

2 — Kilovolt-ampere ratings separated by a dash indicate that all the intervening ratings listed in Table 1 are included.

3 — Bold type - voltages listed in ANSI C84.1-1982.

4 — Italics type - voltages not listed in ANSI C84.1-1982.

Table 18—Other BILs and Associated Percent Impedance Voltages at Self-Cooled (OA) Rating (With, or Without, Load Tap Changing)

BIL (kV)	Percent Impedence Voltage: Without Load Tap Changing	Percent Impedence Voltage: With Load Tap Changing
650	9.50	10.00
825	10.25	10.75
900	10.50	11.0

9. Other Construction Features - General

(See Table 19.)

9.1 Other Bushings

Where distribution insulation levels are specified, the electrical characteristics of bushings shall be as listed for distribution apparatus in ANSI/IEEE C57.12.00-1987.

9.2 Other Neutral Terminations

When specified, other neutral terminations shall be provided as listed in 9.2.1, 9.2.2, and 9.2.3.

9.2.1 Neutral Termination of Y-Connected High-Voltage Windings

When specified, designated neutral terminations of Y-connected high-voltage windings shall be one of the following:

9.2.1.1

The neutral shall be ungrounded and not accessible.

9.2.1.2

The neutral shall be brought through the cover in segment 2.

9.2.1.3

Provision for a future high-voltage neutral bushing shall be made on the cover in segment 2. A fully insulated neutral shall be brought to a terminal board for isolated neutral operation of the transformer.

9.2.1.4

High-voltage windings of transformers with a Y-Δ terminal board supplied in accordance with 9.3(2) shall be available in one of the following constructions:

1) Neutral ungrounded and not accessible
2) Neutral brought through the cover in segment 2

9.2.2 Neutral Termination of Y-Connected Low-Voltage Windings

When specified, one of the following neutral terminations of Y-connected low-voltage windings shall be provided:

1) Permanently Y-connected low-voltage windings shall have the low-voltage neutral bushing furnished as provided for in 9.1
2) Low-voltage windings of a three-phase transformer with a low-voltage Y-A terminal board supplied in accordance with 9.3(2) shall be provided in one of the following constructions:
   a) Without neutral bushing
   b) With a neutral bushing of the same voltage class as that of the winding to which it is connected

9.2.3 Constructions for Neutral Terminations

Neutral terminations, when furnished in accordance with 9.2.1 and 9.2.2, shall be provided in one of the following constructions:

1) Cover-mounted
2) When the transformer construction is in accordance with 9.4, 9.5, or 9.6:
    a) Cover-mounted
    b) Located in the junction box, terminal chamber, or throat, respectively

9.3 Terminal Board

Only one of the following types of terminal boards may be selected for a transformer:

1) A terminal board that provides for a series-multiple connection for transformers listed in the appropriate rating table.
2) A Y-Δ terminal board that provides angular displacements as shown in Figure 4 for transformers with three-phase windings of 110 kV BIL (15 kV nominal system voltage) or less. The other winding of the transformer shall be permanently A-connected.

9.4 Junction Boxes

Junction boxes may be provided for the cable entrance for windings of 110 kV BIL (15 kV nominal system voltage) or less. (See 9.2.3 when neutral termination is required.)

NOTE — Certain kilovolt-ampere and voltage ratings may impose design limitations on the availability or location of these items.

9.4.1

The high-voltage junction box shall either be mounted:

1) On the side of the tank in segment 2, or
2) On the cover in segment 3.

9.4.2

The low-voltage junction box shall either be mounted:

1) On the side of the tank in segment 4, or
2) On the cover in segment 1, provided no high-voltage junction box is on the cover.

9.5 Disconnecting Switches with Interlocks and Terminal Chambers

Disconnecting switches with interlocks and terminal chambers may be provided for the cable connection for windings of 110 kV BIL (15 kV nominal system voltage) or less. (See 9.2.3 when neutral termination is required.)

NOTE — Certain kilovolt-ampere and voltage ratings may impose design limitations on the availability or location of these items.

9.5.1

The high-voltage terminal chamber shall be mounted on the side of the tank in segment 2.

9.5.2

The low-voltage terminal chamber shall be mounted on the side of the tank in segment 4.

Table 19—“Other” Construction Features

Section	Items	kVA, OA Ratings			
		Without Load Tap Changing		With Load Tap Changing	
		750–10 000	12 000–60 000	3750–10 000	12 000–60 000
9.1	Other Bushings	A	—	—	—
9.2	Other Neutral Terminations	A	A	A	A
9.2.1	Y-Connected HV Windings	A	A	A	A
9.2.2	Y-Connected LV Windings	A	A	A	A
9.2.3	Constructions for Neutral Terminations	A	A	A	A
9.3	Terminal Board	A	A	A	A
9.4	Junction Box ≤15 kV	A	A	A	A
9.4.1	HV	A	A	A	A
9.4.2	LV	A	A	A	A
9.5	Disconnecting Switches ≤15 kV	A	A	A	A
9.5.1	HV Terminal Chamber	A	-	A	-
9.5.2	LV Terminal Chamber	A	A	A	A
9.6	Throat Connection ≤15 kV	A	-	A	-
9.6.1	HV Throat	A	-	A	-
9.6.2	LV Throat	A	A	A	A
9.7	Settings and Wiring of Indicator Contacts	A	A	A	A
9.7.1	Settings	A	A	A	A
9.7.2	Wiring	A	A	A	A
9.7.3	Other Temperature Instruments	A	A	A	A
9.8	Current Transformers	A	A	A	A
9.8.1	Bushing-Type Current Transformers	A	A	A	A
9.8.2	Terminal Blocks	A	A	A	A
9.9	Future Forced-Air Cooling	A	A	A	A
9.9.1	Top-Liquid Temperature Control	A	A	S	S
9.9.2	Winding Temperature Control	A	A	A	A
9.10	Pressure Relay	A	A	A	A
9.11	Moving Facilities (Wheels)	>2500	A	A	A
9.12	Surge Arresters	A	A	A	A
9.13	Other Oil Preservation	>5000 kVA	A	<5000 kVA	A
9.14	Other Insulating Liquid	A	-	A	-
9.15	Other Tanks - Bolted Cover	A	A	A	A
9.16	Other Loading	A	A	A	A
9.17	“Other” Tests, per ANSI/IEEE C57.12.00-1980	A	A	A	A
10.	Other Construction — Load-Tap-Changing Transformers	-	-	A	A
10.1	Terminal Blocks	A	A	A	A
10.2	Paralleling Circuit and Operation	-	-	A	A

“S” indicates “standard”

“A” indicates “available, when specified”

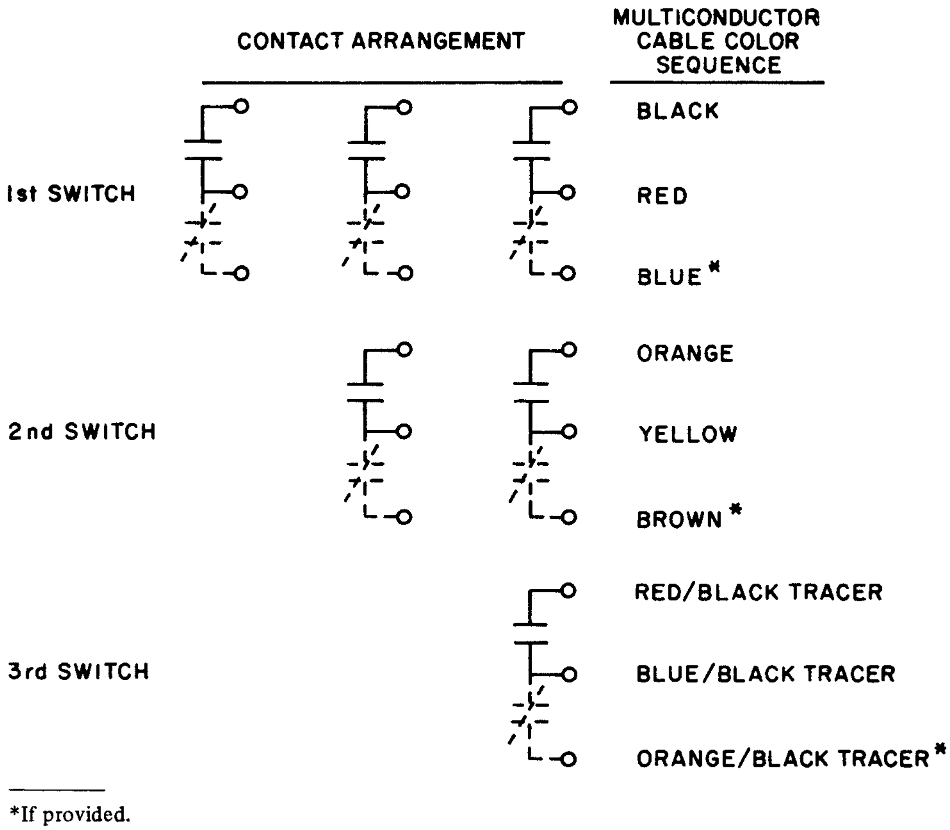


Figure 6—Contact Wiring and Wire Color Coding

9.6 Throat Connection

A throat connection or connections may be provided for windings of 110 kV BIL (15 kV nominal system voltage) or less. (See 9.2.3 when neutral termination is required.)

NOTE — Certain kilovolt-ampere and voltage ratings may impose design limitations on the availability or location of these items.

9.6.1

The high-voltage throat shall either be located:

1) On the side of the tank in segment 2, or
2) On the cover in segment 3, provided a low-voltage throat is not on the cover.

9.6.2

The low-voltage throat shall either be located:

1) On the side of the tank in segment 1 or 4, or
2) On the cover in segment 1, provided a high-voltage throat is not on the cover.

9.7 Temperature and Liquid-Level Indicator Contacts and Wirings

9.7.1

Contacts for liquid-level indicators and temperature indicators shall be in accordance with 7.1.

The liquid-level indicator alarm contacts shall be nonadjustable and shall be set to close at the minimum safe operating level of the liquid.

The liquid-temperature indicator alarm contacts shall be adjustable over a range of 65°C to 110°C.

The winding-temperature simulator contacts shall be adjustable over a range of 95°C to 125°C.

9.7.2 Contact Wiring and Wire Color Coding

Contacts shah be wired with cable having the color coding shown in Figure 6 or with cable having permanent labeling.

9.7.3 Other Temperature Instruments

When specified, eye-level temperature instruments shall be provided.

9.8 Current Transformers

9.8.1 Bushing-Type Current Transformers (or Provision for Their Addition in the Future)

Bushing-type current transformers shall be multiratio with taps as specified by ANSI/IEEE C57.13-1978, and with relay accuracy class (full winding) as listed in Table 20.

There shall be a maximum of two current transformers per bushing, not including current transformers for winding-temperature simulators. Transformers with distribution BIL characteristics shall have a maximum of one current transformer per bushing, not including current transformers for winding-temperature simulators.

Table 20—Recommended Accuracy Classification of Bushing Current Transformers for Relaying Service

Bushing Insulation Class, kV	Bushing Current Transformer Ratio	Accuracy Class at Full Winding Ratio
46 and Below	600:5	C200
	1200:5, 2000:5, 3000:5	C400
	4000:5 and higher	C800
69	600:5	C200
	1200:5	C400
	2000:5 and higher	C800
Above 69	600:5	C400
	1200:5 and higher	C800

All secondary leads shall be brought to an outlet box. Provision shall be made for short-circuiting.

Provision shall be made on transformers 2500 kVA and larger for removing bushing-type current transformers from the transformer tank without removing the tank cover.

When provisions for the addition of future current transformers are required, the user shall so specify.

9.8.2 Terminal Blocks

A nonsplit terminal block shall be provided in a weatherproof enclosure of the nonsplit type, located near the transformer base in segment 1, for terminating contacts specified in 9.8.1 and current transformer secondaries (two leads per current transformer) specified in 9.9.1.

9.9 Provision for Future Forced-Air Cooling

9.9.1

When class OA transformers are to have provision for future forced-air cooling and the control of the forced-air equipment is to be by the winding temperature, the following equipment shall be provided:

1) the necessary mechanical arrangement
2) a thermally operated winding-temperature conmal element mounted in a well
3) provision for mounting the control cabinet
4) provision for mounting the fans

9.9.2

When class OA transformers are to have provision for future forced-air cooling and the control of the forced-air equipment is to be by the winding temperature, the following equipment shall be provided:

1) the necessary mechanical arrangement
2) a thermally operated winding-temperature control device with the thermal element mounted in a well
3) a heating coil
4) a low-voltage current transformer
5) provision for mounting the control cabinet
6) provision for mounting the fans

NOTE — Information concerning fans and controls is given in 5.9.

9.10 Pressure-Type Relay

A pressure-type relay shall be provided for the indication of transformer faults.

9.11 Moving Facilities

Flanged wheels for a 1.435-meter (56-1/2-inch) rail gage for motion parallel to the centerline of segments I and 3 shall be available for 2500 kVA and larger transformers.

9.12 Surge Arresters

The following types of construction are available for surge protection:

1) Provision only for the mounting of surge arresters.
2) Mounting complete with surge arresters.
3) A surge arrester ground pad consisting of a tank grounding pad (in accordance with 5.5) that is mounted near the top of the tank and that may be specified for each set of arresters - except that individual ground pads may

be supplied where the separation of the arrester stacks is such that individual pads for grounding each phase attester represent better design.

NOTE — Material for connecting surge arresters to live parts and to ground pads is not included in 9.13(1) through 9.13(3).

9.13 Other Oil Preservation Systems

When specified, other systems of oil preservation shall be provided on transformers rated above 5000 kVA as follows:

1) Inert-gas pressure system. An inert-gas pressure system is a system in which by means of a positive pressure of inert gas maintained from a separate inert-gas source and reducing valve system, the interior of the transformer shall be sealed from the atmosphere through a top-oil temperature range of 100°C. The internal gas pressure shall not exceed 8 psi (55.2 kPa) gage.
2) Conservator or expansion-tank system. A conservator or expansion-tank system is a system that by means of an auxiliary tank partly filled with oil and connected to the completely filled main tank, seals the oil in the main tank from the atmosphere through a top-oil temperature range of 100°C. The internal top-oil pressure in the main tank shall not exceed 5 psi (34.5 kPa) gage.
3) Gas-liquid seal system. A gas-liquid seal system is a system in which the interior of the transformer, by means of an auxiliary tank or tanks that provide a liquid seal operating on the manometer principle, shall be sealed from the atmosphere through a top-liquid temperature range of 100°C, and the gas plus liquid volume shall vary such that the internal gas pressure will not exceed 5 psi (34.5 kPa) gage, positive or negative.

9.14 Other Insulating Liquid

When specified, another suitable insulating liquid shall be furnished instead of mineral oil.

NOTE — Some “other insulating liquids” may have technical limitations (such as voltage) that may limit their scope of application.

9.15 Other Tanks

When specified, a bolted main cover shall be provided.

9.16 Other Loading

ANSI/IEEE C57.92-1981 provides guidance and information concerning loading under various conditions, some of which may be limited by the capability of the ancillary components of the transformer. When specified, ancillary components and other construction features (cables, bushings, tap changers, liquid expansion space, and the like, shall be supplied in such a way that they in themselves will not limit the loading to less than the capability of the windings.

NOTE — ANSI C57.92-1981 is not a standard. It provides the best known general information for loading transformers under various conditions based on typical winding insulation systems and is based upon the best engineering information available at the time of preparation. It discusses “limitations” of ancillary components other than windings that may limit the capability of transformers to meet its guidelines.

9.17 “Other” Tests

When specified, “Other” Tests as described in ANSI/IEEE C57.12.00-1987 shall be performed.

10. Other Construction Features—Load-Tap-Changing Equipment

10.1 Terminal Blocks

In a load-tap-changing transformer, terminal blocks shall be provided in the load-tap-changing control cabinet for terminating contacts specified in 9.8.1 and current transformer secondaries (two leads per current transformer) specified in 9.9.1.

10.2 Paralleling Circuit and Operation

Figure 7 shows a simplified schematic for the circulating current paralleling of two transformers. The following defines part of this schematic:

1) I_p, with terminals 5 and 6, are the paralleling current inputs to the two control devices.
2) T_s is a circulating current sensitivity device. Other means are available to accomplish the variable sensitivity that is necessary to prevent tap-changer hunting at one extreme, or to prevent failure of the two tap changers to come together at or near the same tap at the other extreme.
3) When specified, K_c is a current relay to detect excessive circulating current, block the tap changer, and sound an alarm.
4) Contacts 52a/I, 52b/I, 52a/II, 52b/II are on the circuit breakers tying transformers I and II to the load bus.
5) Contacts 24a and 24b are on a breaker used to divide the bus and permit independent operation of one or both transformers.

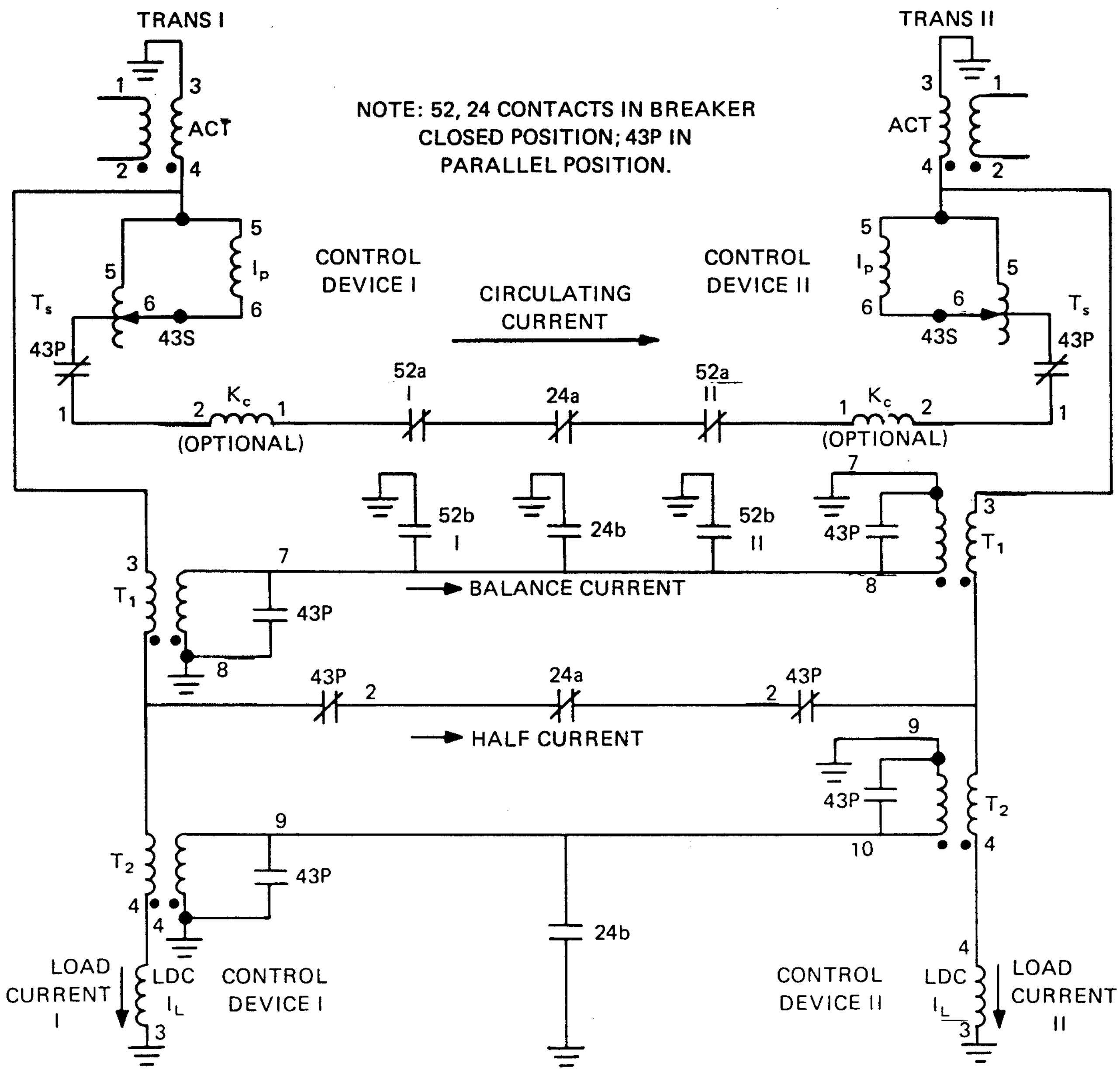
   NOTE — The circuit breaker contacts are shown in the breaker closed position.
6) The first horizontal conductor has a current analogous in angle and magnitude to the reactive current circulating through the two transformers.
7) The second line has a balance current which forces the two load currents to be identical. Therefore any difference must flow through the circulating current path.
8) If one transformer, say #II, is taken out of service by opening breaker 52/II then half of the #I load current is forced to flow through the half-current-loop. In this way transformer control #I sees half the load current that it saw previously and the proper amount of line-drop compensation in the #I control is maintained.
9) The same configuration, grounding points, etc, must be maintained if transformers are to be successfully paralleled.

10.3 Omission of Automatic Load-Trap-Changing Control

When specified, automatic load-tap-changing control shall be omitted.

10.4 Lightning Surge Voltage Protector for Motor Power Supply

When specified, a lightning surge arrester shall be provided for surge protection of load-tap-changing motor power supply.



Note: 52 and 24 contacts are shown in the breaker closed position; 43P in the parallel position.

Figure 7—Simplified Schematic of Current Circuit for Paralleling Two Transformers