Vacuum Hold Time

kV class	Vacuum hold time in hours
69 kV	12 or more
138 kV	24 or more
230 kV	48 or more
345 kV	48 or more
500 kV	60 or more
765 kV	60 or more

Table 1 Vacuum Hold Time

High-Voltage Winding Voltage Class				
≤ 69	115	230	345	500
6 (all)	6 (all)	6 (all)	12 (all)	12 (all)
4 + T (all)	4 + T (all)	4 + T (all)		8 + T (all)
8 + t (aged)	8 + t (aged)	8 + t (aged)		12 (aged)
18 – new (sectional tank)	18 – new (sectional tank)	18 – new (sectional tank)		
14 – new up to 1 month after shipment (sectional tank)	14 – new up to 1 month after shipment (sectional tank)	14 – new up to 1 month after shipment (sectional tank)		

* For new transformers, follow manufacturer's recommendations or better.
T = 1 hour for each hour the core & coils were exposed, T not to exceed 8 hours.
t = 1 hour for each 8 hours of open time.

Suggest retaining the existing vacuum hold time guideline in C57.93 but with Additional periodic heating cycle to address the heat of vaporization issue.
Reason: transformer insulation is greatly affected by moisture content and therefore we need to ensure a good dry transformer.

- C57.93 is more stringent
- No further benefit if > 24 hours
  - "free water @ room temperature freezes @ 4 torr"
  - " heat of vaporization would lower the temperature to a point where remaining water will freeze making extensive vacuuming pointless"
- Difficult to define "open time", therefore hard to quantify T and/or t.
- Suggestion, use dew point to judge vacuum hold time.

Vacuum Hold Time

kV class	Vacuum hold time in hours
69 kV	12 or more
138 kV	24 or more
230 kV	48 or more
345 kV	48 or more
500 kV	60 or more
765 kV	60 or more

Table 1 Vacuum Hold Time

High-Voltage Winding Voltage Class				
≤ 69	115	230	345	500
6 (all)	6 (all)	6 (all)	12 (all)	12 (all)
4 + T (all)	4 + T (all)	4 + T (all)		8 + T (all)
8 + t (aged)	8 + t (aged)	8 + t (aged)		12 (aged)
18 – new (sectional tank)	18 – new (sectional tank)	18 – new (sectional tank)		
14 – new up to 1 month after shipment (sectional tank)	14 – new up to 1 month after shipment (sectional tank)	14 – new up to 1 month after shipment (sectional tank)		

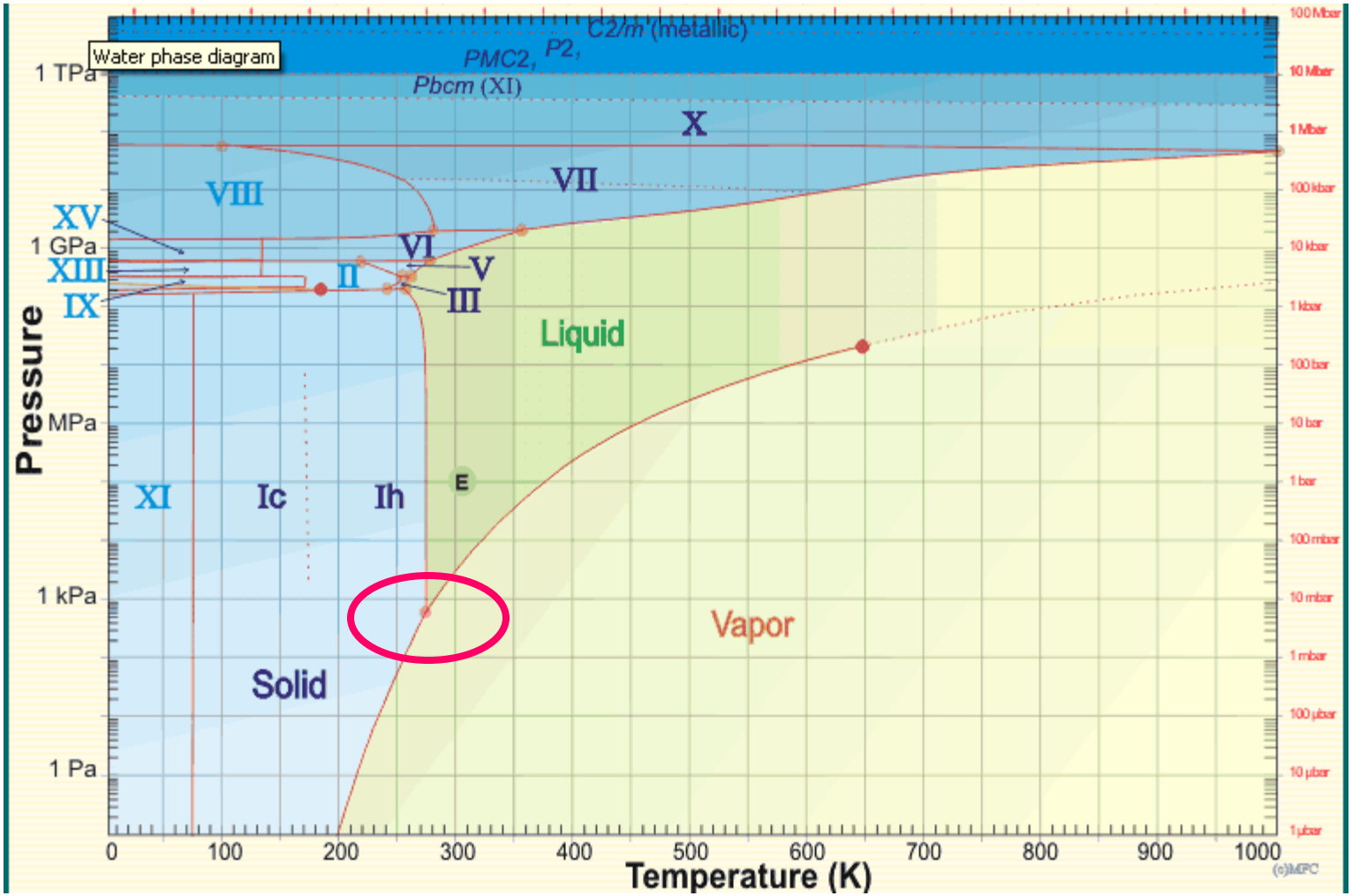
* For new transformers, follow manufacturer's recommendations or better.
T = 1 hour for each hour the core & coils were exposed, T not to exceed 8 hours.
t = 1 hour for each 8 hours of open time.

Suggest retaining the existing vacuum hold time guideline in C57.93 but with Additional periodic heating cycle to address the heat of vaporization issue. Reason: transformer insulation is greatly affected by moisture content and therefore we need to ensure a good dry transformer.

- Roger Hayes:
  Table # 1
- I can agree with leaving this table as is even though I believe 12 hours for 69 kV is more than adequate, however, we need to somehow address voltages < 69 kV were 12 hours is too long and introduces costly processing at the site. I would suggest 8 hours for < 69 kV.
- As vacuum time should be continuous, then any "periodic heating cycle" may have to be by short circuit current application, which may not be practical in the field.

- Mike Lau – Heating cycle could be achieved by filling with hot oil to heat up the winding and draining it. This could be repeated several times.

Phase Diagram of Water



Hold time and Set time

For New units

Voltage class	Hold time before energization (hours)
69 kV	12
138 kV	24
230 kV	24
345 kV	48
500 kV	48
765 kV	72

Table 2

For old and reprocessed units

-Recommended minimum set time (absorption), after final oil filling of reprocessed units

Voltage class (kV)	Minimum set time, absorption (hours)
69	48
138	48
230	48
345	60
500	72
765	96

Table 4

- No reason for Old Units to take longer time for impregnation – reverse could be true as it depends how long the core and coil is left without oil
- Suggest Table 2 and Table 4 should be combined into one table

Agreed, These two tables should be resolved into one.

Hold time and Set time

For New units

Voltage class	Hold time before energization (hours)
69 kV	12
138 kV	24
230 kV	24
345 kV	48
500 kV	48
765 kV	72

Table 2

For old and reprocessed units

-Recommended minimum set time (absorption), after final oil filling of reprocessed units

Voltage class (kV)	Minimum set time, absorption (hours)
69	48
138	48
230	48
345	60
500	72
765	96

Table 4

- Roger Hayes:
  The tables should be combined into one, however, if reprocessing is required for reasons as sited in clause 4.10, (Note: 4.10 is on Reprocessing) then the higher times should be followed.
- For 69 kV. 48 hours is excessive. I suggest 24, which is still longer than I have used over the years. For < 69 kV, these times could be reduced.

Agreed, These two tables should be resolved into one.

Hold time and Set time

For New units

Voltage class	Hold time before energization (hours)
69 kV	12
138 kV	24
230 kV	24
345 kV	48
500 kV	48
765 kV	72

Table 2

TABLE 16
Doble Client Reported
Pump Run and Stand Time in Hours

		High-Voltage Winding Voltage Class				
		≤ 69	115	230	345	500
Units with Pumps	Pump Run Time, ½ of pumps, each half	2	2	2	2	2
		Also: 4	Also: 4	Also: 4	__**	__**
	Stand Idle Time, Minimum	24	24	24	48 44 24	68
		Also: 4 12 44	Also: 12 44	Also: 44	Also: 12	Also: 48
Units without Pumps	Stand Idle Time, Minimum	48	48	48	48 24	72

** No information was given for stand times in these situations. It is recommended to choose conservative times for a safe outcome.

- Doble has different criteria for units with and without pump.
- Doble specifies time for running pumps
- Suggestion to run half of the pumps for 2 hr and other half for another 2 hrs. Why not run all the pumps at once?

Yes, we should include the recommendation of running the pumps. (why not running both pumps at the same time??) Also, change time for 69KV to 24 hours?

Hold time and Set time – Running Pumps

- Kipp Yule: “A cautionary statement regarding static-electrification should be included regarding running all or many oil pumps with cold oil, dry oil, and high velocity oil velocity. This is also called Streaming Charging, which is well explained in the NYNAS OIL Handbook chapter 3-18. If Oil Pumps are used then the recommend the electrostatic charging tendency (ECT) be measured & monitored. Also, known as:
- Streaming Charging uC/m³

Mike Lau:
I read up Streaming Electrification in the Nynas Transformer Oil Handbook. It is on Section 5.17 (P.109 - P110) on my copy.

- It describes the problem is more likely to occur when the oil has a flow speed exceeding 0.5 m/sec. (I don't think this number means much to most users. Not sure if this could be roughly converted to the capacity of the oil pumps).
- It also indicates that well refined and inhibited oil would have lesser streaming charging.

Paul Mushuill:
I am also concerned about running pumps for two hours. I do not think that we can blindly state to run pumps without some precautions. If you are in Phoenix or Florida, it is not a concern but most of us are going to have much cooler oil.

Yes, we should include the recommendation of running the pumps. (why not running both pumps at the same time??) Also, change time for 69KV to 24 hours?

Vacuum Level

Table 3

Voltage class (kV)	Vacuum (mm Hg) final oil filling
69	1000 microns, (1 mmHg)
138	1000 microns, (1 mmHg)
230	1000 microns, (1 mmHg)
345	750 microns, (0.75 mmHg)
500	500 microns, (0.5 mmHg)
765	500 microns, (0.5 mmHg)

TABLE 6
Doble Client Reported Vacuum Pressures, Max., Prior to Oil Filling

	High-Voltage Winding Voltage Class				
	≤ 69	115	230	345	500
Practices of majority of reporting participants	2 mmHg	2 mmHg	0.5 mmHg 1 mmHg 2 mmHg	0.5 mmHg 1 mmHg	0.5 mmHg 1 mmHg
Additional practices reported	Also: 4 mmHg or 0.1 mmHg*	Also: 4 mmHg or 0.1 mmHg*	Also: 0.1 mmHg*	Also: 0.1 mmHg*	Also: 0.1 mmHg*

- Suggest 2mm Hg for 69 KV; 1 mm Hg for 230KV; and 0.5 mm Hg for 345KV and above.
- Suggest Table 3 to be tied in with Table 1 (Vacuum hold time)
- Suggest to use Total Dissolved Gas : <5000 ppm; or 2500ppm for conservator type
- Suggest to use Piper Chart to determine the vacuum level in order to achieve 0.5% moisture content.

- Roger Hayes:
  I can agree with your suggestion, despite believing that 1000 microns at 69 kV is more than adequate, however for

  < 69 kV it should be 2000 microns

Suggest No Change.

Soak Time

Table 5 —Recommended minimum energization time at no load

Voltage class	Energizing period (hours)	Suggested minimum energizing period (hours)
230 kV – 800 kV	24	12
120 – 170 kV	12	8
< 120 kV	8	8

Note: this is what known as soaking time.

- Should not provide two sets of criteria –"everybody will go for the minimum !".
- One suggestion : all 24 hours
- One suggestion : > 325kV 12 hrs; < 325KV 4 hrs
- One suggestion : >230KV, 72 hrs; <230KV 24 hrs

Suggest 69 KV and below – 8 hrs, > 69KV – 12 hours

Soak Time

Table 5 —Recommended minimum energization time at no load

Voltage class	Energizing period (hours)	Suggested minimum energizing period (hours)
230 kV – 800 kV	24	12
120 – 170 kV	12	8
< 120 kV	8	8

Note: this is what known as soaking time.

- Roger Hayes: I agree with your suggestion if it applies to “minimum energizing period”, however, although somewhat subjective, I have always recommended 24 hours if there is no time penalty.

- Paul Mushill: My biggest concern is the energized at no load soak time. When a transformer is ready to go and energized, our normal commissioning usually takes 8 to 16 hours. After that, operations is pushing to apply load and put in service. If we have to wait a day or two, our testers have to come back out to do load checks after applying load. I do not see any benefit to this soak time over the normal 8 hours commissioning time. If more soak time is required, I would like for some manufactures’ representatives explain the benefits and purpose and convince us that this is really necessary.

Suggest 69 KV and below – 8 hrs, > 69KV – 12 hours

TABLE 7
Recommended Vapor Pressure, Max., Prior to Oil Filling Necessary to Achieve Indicated Percent Weight in Paper

Vapor Pressure, microns			
Temp (C)	1.0% Moisture	0.7% Moisture	0.5% Moisture
10	80	44	24
20	188	103	58
30	406	227	130
40	835	479	280
50	1656	986	585
60	3198	1987	1197
70	6041	3933	2403
80	11208	7672	4766

- Should this table be included? (Looks like Piper Chart)

Is this the Piper Chart? Table does have some good information.
Should we also include 0.3% moisture?

TABLE 13
Doble Client Reported Vacuum Hold Times, Hours Minimum, After Oil Filling

	High-Voltage Winding Voltage Class				
	60 or 69	**115**	**230**	**345**	**500**
Practices reported by most participants	2	2	2	3	4
Additional practices reported	0.5 – 1* 0	0.5 – 1* 0	0.5 – 1* 0	0.5 – 1* 0	

* This vacuum hold time coordinates with the 0.3 mmHg maximum vacuum requirement during oil filling. If the vacuum during the fill went higher than 0.5 mmHg, the vacuum is to be maintained for over one hour after fill.

- Is this necessary?
- "Concern potential for creating suspended bubbles in the oil resulted from residual gas"

Suggest don't include

Other Comments

- C57.93 should provide a definite dryness acceptance criteria e.g. Doble PF ? Moisture Content ? Dew Point?
- Confusing units: mm Hg, torr, inches of Hg, Pascal,
- Include conversion table
- Use limits of Dissolved Gas – to minimize amount of oxygen
- Update Maintenance sections

1. There will be sensor available to measure moisture in paper directly.
2. Yes, will include a Conversion Table.
3. Yes, use C57.106 guideline for total dissolved gases
4. Yes.

Other comments: Cold Trap

- Kipp Yule:
  For field dry out of large units, I find it is useful to use a cold trap to measure the rate of moisture removal rather than just a time based process. If the operator knows the weight of the insulation and the moisture content at start, then the quality of moisture to be removed and be determined and measure. Usually needs some OEM details to have accurate insulation weight.
- While the above is not new, it is only offered from the point of view if it should be included in C57.93.

Mike Lau:
As for the cold trap. My understanding that they offer very efficient and fast removal of moisture vapour:

- Here is the quote from Baron USA:
  - One pound of water becomes 100 cubic feet of water vapor at 100 Torr.
  - One pound of water becomes 10,000 cubic feet of water vapor at 1 Torr.
  - A cold trap condenses that vapor into a solid ahead of the vacuum pumps.
  - That vapor then does not have to be removed by the vacuum system.
  - That water can then be measured.

Alan Peterson:
We have had good results using cold traps. They are easily installed in the vacuum line. We fabricated ours in our shop from aluminum with a double wall container. We use liquid nitrogen for the coolant. The frozen moisture is scraped out of the inner container and allowed to melt and be measured. On the subject of oil electrification, we have found that different designs of oil pumps can contribute to this problem. Pumps designed with the output directly entering the tank or tank gussets have a greater propensity for this phenomenon than pumps that have the output connected to the tank or tank gussets through a 90 degree elbow.

- I can only surmise that this is caused by allowing the oil to remain in greater contact with grounded metal parts for a longer period of time before entering the main tank.