Working Group - C57.104 IEEE Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers

IEEE/PES Transformers Committee

Spring 2025 Meeting

Meeting # 2

Power & Energy Society®

Agenda

- 1. Welcome — E. teNyenhuis
- 2. Circulation of Attendance Rosters — Sami Debass
- 3. Approval of Agenda — E. teNyenhuis
- 4. Approval of Fall 2024 WG Meeting Minutes — E. teNyenhuis
- 5. DGA data collection update — E. teNyenhuis
- 6. Guide change presentations
  - 1. Toni Mellin
  - 2. Zack Draper
  - 3. Andrew Larison
- 7. Review last meeting agreed actions and new actions — E. teNyenhuis
- 8. New Business — E. teNyenhuis
- 9. Adjournment — E. teNyenhuis

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- IEEE SA Copyright Policy, see
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  https://standards.ieee.org/about/policies/bylaws/sect6-7.html#7
  Clause 6.1 of the IEEE SA Standards Board Operations Manual
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- IEEE SA Best Practices for IEEE Standards Development
  - http://standards.ieee.org/develop/policies/best_practices_for_ieee_standards_development_051215.pdf
- Distribution of Draft Standards (see 6.1.3 of the SASB Operations Manual)
  - https://standards.ieee.org/about/policies/opman/sect6.html

Call for Patents

Draft – Work in Progress

- Participants shall inform the IEEE (or cause the IEEE to be informed) of the identity of each holder of any potential Essential Patent Claims of which they are personally aware if the claims are owned or controlled by the participant or the entity the participant is from, employed by, or otherwise represents
- Participants should inform the IEEE (or cause the IEEE to be informed) of the identity of any other holders of potential Essential Patent Claims

Early identification of holders of potential Essential Patent Claims is encouraged

Call for Patents

Draft – Work in Progress

- **Cause an LOA to be submitted to the IEEE SA (patcom@ieee.org); or**
- **Provide the chair of this group with the identity of the holder(s) of any and all such claims as soon as possible; or**
- **Speak up now and respond to this Call for Potentially Essential Patents**

If anyone in this meeting is personally aware of the holder of any patent claims that are potentially essential to implementation of the proposed standard(s) under consideration by this group and that are not already the subject of an Accepted Letter of Assurance, please respond at this time by providing relevant information to the WG Chair

Patent-related information

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The patent policy and the procedures used to execute that policy are documented in the:

- ***IEEE SA Standards Board Bylaws*** **(http://standards.ieee.org/develop/policies/bylaws/sect6-7.html#6)**
- ***IEEE SA Standards Board Operations Manual*** **(http://standards.ieee.org/develop/policies/opman/sect6.html#6.3)**

Material about the patent policy is available at
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    - Relative costs of different technical approaches that include relative costs of patent licensing terms may be discussed in standards development meetings.
      - **Technical considerations remain the primary focus.**
  - **Don't discuss or engage in the fixing of product prices, allocation of customers, or division of sales markets.**
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For more details, see *IEEE SA Standards Board Operations Manual*, clause 5.3.10 and
***Antitrust and Competition Policy: What You Need to Know* at http://standards.ieee.org/develop/policies/antitrust.pdf**

Membership List – 81 Total

Mario Alonso	Florin Faur	Luc Loiselle	Amitabh Sarkar
Paul Boman	Todd Felton	Stephanie Mabrey	John Sinclair
Edward Casserly	Miguel Fernandez	Kumar Mani	Yong Tue SOHN
Juan Castellanos	Marcos Ferreira	Kushal Mahajan	Mauricio Soto
Sudip Chanda	Bruce Forsyth	Toni Mellin	Brian Sparling
Stuart Chambers	Miguel Garcia	Emma Murkowski	Brad Staley
Mark Cheatham	James Gardner	David Murray	Greg Steeves
Luis Cheim	Ramsis Girgis	Mark Newbill	Troy Tanaka
Randy Cox	Luis Gonzalez	Parminder Panesar	Ed teNyenhuis
Sami Debass	Alireza Gorzin	Poorvi Patel	Ryan Thompson
Gabriel Delgado	Giovanni Hernandez	Vinay Patel	Mark Tostrud
Lee Doyle	Andy Holden	Rakesh Patel	EdteNyenhuis
Zachary Draper	Traci Hopkins	Nick Perjanik	Cole Van Drell
Roberto DA Siliva	John John	John Pruente	Alwyn Vanderwalt
Jesse Duffy	Egon Kirchenmayer	Ion Radu	Rogerio Verdolin
James Dukarm	Dmitriy Klempner	Tim Raymond	Dharam Vir
Morales - Cruz Emilio	Donald Lamontagne	Scott Reed	Drew Welton
Will Ellitt	Lance Lewand	Arash Razvan	Daniel Weyer
Marco Espindola	Jinming LI	Yuri Rossini	Bill Whitehead
Zlatan Fazlic	Weijun Li	Mickel Saad	Deanna Woods
			Shuzhen Xu

Approval of Agenda

1.	Welcome	E. teNyenhuis
2.	Circulation of Attendance Rosters	Sami Debass
3.	Approval of Agenda	E. teNyenhuis
4.	Approval of Fall 2024 WG Meeting Minutes	E. teNyenhuis
5.	DGA data collection update	E. teNyenhuis
6.	Guide change presentations 1. Toni Mellin 2. Zack Draper 3. Andrew Larison	
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8.	New Business	E. teNyenhuis
9.	Adjournment	E. teNyenhuis

Approval of Minutes of Last Meeting

- This was the first working group for the revision of C57.104
- The Chair, Ed teNyenhuis, led the meeting. The Chair introduced the Vice-Chair, Luiz Cheim, and the Secretary, Sami Debass who recorded the attendance and meeting minutes.
- There were 134 persons in attendance (see list below). There were 8 persons requesting membership and 37 guests. Since this was the first meeting, quorum was reached.
- The Meeting Agenda was reviewed. A motion to approve the agenda was made by Mickel Saad and seconded by Marko Teofanovic. The agenda was unanimously approved.
- The TF Spring 2024 Meeting Minutes were reviewed. Toni Mellin moved to approve the agenda, which was seconded by Mario Alonso. The minutes were unanimously approved.
- A call for patents was made with no response.
- The Chair earlier invited members to present suggested changes to the guide using a presentation template. The working group had 4 presentations discussed below.
- Presentation # 1 – Luiz Cheim - Section 6.1 & 6.2 - What to do with online monitoring data versus laboratory data.
    - There are differences in results between different monitoring technologies and the lab technology
    - A motion was made by Emilio Morales-Cruz and seconded by Matt Chu to create a task force to investigate this matter to potentially include in this guide, create a new guide, or publish a white paper. The motion was approved.
- Presentation # 2 – Ramsis Girgis - Create a new section in the guide about 6-8:1 H2 to CH4 ratio generation caused by moderate overheating of thin oil film between laminations of core
    - Based on publications by Ramsis Girgis and Ed teNyenhuis in 2009 (already cited in the guide)
    - It may be included in the Annex E Case Studies Section
    - Ramsis Girgis made a motion (seconded by Evgenii Ermakov) to write and submit text to the WG for inclusion in the guide. The motion was approved.

Approval of Minutes of Last Meeting

- Presentation # 3 - Don LaMontagne - Discussion on Section A.3 Future Work
    - It was proposed to use Artificial Neural Networks in the guide as a new clause (for online and offline DGA)
    - Don LaMontagne suggested creating an online repository of a failure database with pre-failure DGA and RCA results that can be used to train future classification algos
    - Lance Leward made a motion (seconded by Stuart Chambers) that this should be rolled into the earlier approved TF about online monitoring. This motion was approved.
- Presentation # 4 - Rainer Frotscher- Flowchart in 6.1.1: should be AND instead OR in the second decision diamond
    - This would significantly reduce the number of transformers that end up as Status 3, moving those other results to Status 2.
    - The data set that was used in Annex A was "destroyed" so we cannot run the change in the flow chart algorithm to perform any statistics.
    - Sami Debass requested that we create an anonymous data repository.
    - IEEE is doing this for esters to collect and anonymize the data and pass it to the transformer committee.
    - Patrycja Jarosz from IEEE SA gave information about how the existing esters database works if we wanted to go forward with a similar process for the creation of an IEEE database.
    - Tim Raymond made a motion (Adrina S Cisco seconded) for the WG chair to begin a discussion with IEEE for the creation of an anonymized DGA mineral oil database. This motion was approved.

Approval of Minutes of Last Meeting

- There was insufficient time for the other 2 presentations prepared but these will be discussed in a virtual working group meeting in Jan / Feb 2025.
- There was no new business to discuss.
- The meeting was adjourned at 15.00.

DGA Data Overview

- Completed files to be emailed to c57data@ieee.org
- IEEE staff will anonymize the files and then forward to the WG
- All WG members will have access to the data
- Data will be retained after revision of the guide
- Laboratory DGA sample template
- Gas Monitor template

Laboratory DGA Template

DGA Laboratory Samples Template

Scope:	This data will be anonymized and used for development of gas limits by the Working Group for the revision of IEEE Standard C57.104
Instructions:	Mineral Oil data only (no ester, no silicone)
	In service data only (no factory test data)
	Transformer main tank DGA data only (no LTC compartment DGA data)
	Enter data in the "Data Entry" worksheet
	Column A - leave blank. IEEE staff will assign a unique identifier to this row of data
	Column B is the transforrmer serial number. This will be later anonymized by IEEE staff and not visible to the IEEE C57.104 working group
	Column C is the transforrmer name. This will be later anonymized by IEEE staff and not visible to the IEEE C57.104 working group
	Coumns D to M are the minium data (DGA results)
	Columns N - X are "Optional Data" - this will support the analysis if provided

Send data files to : c57data@ieee.org

Subject Line: C57.104 Laboratory Data Submission

Laboratory DGA Template

	A	B	C	D	E	F	G	H	I	J	K	L	M
1				Minimum Data									
2	Unique Data Identifier (added by IEEE)	**Transformer Serial Number** (unique identifier) To be ANONYMIZED by IEEE	**Transformer Name** (unique identifier) To be ANONYMIZED by IEEE	**Date of Sampling**	**H2 [ppm]**	**CH4 [ppm]**	**C2H6 [ppm]**	**C2H4 [ppm]**	**C2H2 [ppm]**	**CO [ppm]**	**CO2 [ppm]**	**O2 [ppm]**	**N2 [ppm]**
3													
4	example	2351002	T67	1-Dec-24	58	12	5	18	1	780	5796	19247	63522
5													

N	O	P	Q	R	S	T	U	V	W	X
Optional Data										
Year Built	**Max kV**	**Max MVA**	**Oil Volume**	**Oil Volume Unit**	**Cooling Type**	**OLTC** (menu)	**Oil Preservation Type** (menu)	**Paper Type** (menu)	**Application** (menu)	**Notes**
1992	230	500	12536	Liters	ONAF	In-Tank OLTC	Free Breathing	TUK	Generation	

Gas Monitor Template

DGA Gas Monitor Data Template

Transformer and Gas Monitor Information

Scope:	This data will be anonymized and used for development of gas monitor limits by the Working Group for the revision of IEEE Standard C57.104
Instructions:	Use a separate excel file for each transformer
	Hourly data is recommended
	In service data only (no factory test data)
	Transformer main tank DGA data only (no LTC compartment DGA data)
	Mineral oil data only
	Enter the data below about the transformer and gas monitor
	If the Gas Monitor is a composite gas type, enter the composite value in "Composite Value" column
	User/Owner, Tranformer Name and Gas Monitor Make/Model will be anonymized by IEEE Staff.
	The Gas Monitor Make and Model will be converted to a generic Gas Monitor Type Code and generic Gas Monitor Sensor Type by IEEE Staff
	Copy the gas monitor data into the "Gas Monitor Download" worksheet

Send date files to: c57data@ieee.org

Subject Line: C57.104 Gas Monitor Data Submission

Gas Monitor DGA Template

User / Owner (unique identifier) To be ANONYMIZED by IEEE Staff)	example
Transformer Name (unique identifier) To be ANONYMIZED by IEEE Staff	T12
Transformer Serial Number (unique identifier) To be ANONYMIZED by IEEE Staff	2503698
Gas Monitor Make and Model To be ANONYMIZED by IEEE Staff	ABB M10
Transformer max MVA	120
Transformer max kV	69
Transformer year built	1995
Transformer cooling type	ONAF
Oil Volume	23586
Oil Volume units	liters
Comments on any issues, failures (enter free text)	no issues
Gas Monitor Type Code - leave blank (added by IEEE staff using a conversion chart)	
Gas Monitor Sensor Type - leave blank (added by IEEE staff using a conversion chart)	
Unique Data File Identifier - leave blank (added by IEEE staff)	

Gas Monitor Template

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Time stamp of Sampling**	**H2 [ppm]**	**CH4 [ppm]**	**C2H6 [ppm]**	**C2H4 [ppm]**	**C2H2 [ppm]**	**CO [ppm]**	**CO2 [ppm]**	**O2 [ppm]**	**N2 [ppm]**	**Fluid Temperature [ºC]**	**Ambient Temperature [ºC]**	**Total Gas Pressure [mbar] or [hPa]**	**Composite Gas Value (if applicable)**
2														
3														
4														

Gas Monitor Conversion Chart

- Need to create Gas Monitor conversion chart for all commercial gas monitors
- Convert to Monitor Type and Sensor Type
- Need volunteers

Monitor Type	Gases Monitored
M9	H_2, CH_4, C_2H_4, C_2H_6, C_2H_2, $C0$, $C0_2$, O_2, N_2
M8	H_2, CH_4, C_2H_4, C_2H_6, C_2H_2, $C0$, $C0_2$, O_2
M7	H_2, CH_4, C_2H_4, C_2H_6, C_2H_2, $C0$, $C0_2$
M6	H_2, CH_4, C_2H_4, C_2H_6, C_2H_2, $C0$
M5	H_2, CH_4, C_2H_4, C_2H_2, $C0$
M3	CH_4, C_2H_4, C_2H_2
M2	H_2, $C0$
M1	H_2
M1*	H_2 composite and other gases

Sensor Type	Description
GC	Gas Chromatography
NDIR	Non dispersive Infra Red
PAS	Photo Acoustic Spectroscopy
FTIR	Fourier Transformer Infra Red
TCC	Thermal conductivity cell
EC	Electrochemical cell
MetOx	Metal-oxide sensor
MetFilm	Metal film sensors

Invitation Letter (pending IEEE Legal approval)

Dear PC57.104 working group members:

As discussed in our first working group meeting, the working group would like to receive DGA data to assist in the development of gas criteria for the IEEE Standard C57.104 revision. This DGA data is being requested for traditional DGA laboratory samples and for gas monitors. There are 2 attached excel template files (one for laboratory samples, one for gas monitor downloads) that can be used. The data details are explained in the excel template files.

The transformer serial number and transformer identifier are requested, but this will be anonymized by IEEE staff so that the working group will not have any identity information on the data. In addition, the gas monitor brand is requested for the gas monitor DGA data, but this will be converted to generic gas monitor codes by IEEE staff using a conversion chart.

Once you have prepared the data files, they should be emailed directly to IEEE at c57data@ieee.org with the subject lines "C57.104 Laboratory Data Submission" or "C57.104 Gas Monitor Data Submission". IEEE staff will anonymize the data and then send to the working group for whatever analysis and calculations are to be done.

The data files will be retained by the working group for future reference. All members of the working group will have access to the data.

If you have any questions on the IEEE anonymization, please contact Patrycja Jarosz at p.jarosz@ieee.org.

If you have any questions on the data file templates, please contact Ed teNyenhuis, the C57.104 working group chair, at edt@ieee.org.

Thank you for your assistance

Plan for Data Analysis

- Team to receive data (from IEEE), clean, compile, store
- Perform data analysis for laboratory samples
- Perform data analysis for gas monitor data
- Determine impact on gas threshold tables
- Develop potential gas monitoring limits
- Present findings to working group
- Data Analysis Task Force – need volunteers
- How long to leave data submission open?

Section xx.xx – Toni Mellin

- Topic: Mistakes in Duval triangle 4 & 5
- C57.104-2019 contains mistakes in how Duval triangles 4 & 5 are defined, as compared to the **source material excel file** in C57.104-2019 downloads.zip

[11] Free algorithms for using the Duval Pentagons methods are available in the IEEE Std C57.104-2019 directory located at: https://standards.ieee.org/content/dam/ieee-standards/standards/web/download/C57.104-2019_downloads.zip.

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Section xx.xx – Toni Mellin

– Topic: Mistakes in Duval triangle 4 & 5

– Example 1

Table D.3—Fault zone boundaries for Figure D.3

Gas% / Fault	% H_2	% CH_4	% C_2H_6
PD	—	≥ 2 and < 15	< 1
S	≥ 9	—	≥ 30 and < 46
	≥ 15	—	≥ 24 and < 30
	—	< 36	≥ 1 and < 24
	—	< 36 and ≥ 15	< 1
	—	< 2	< 1
O	< 9	—	≥ 30
C	—	≥ 36	≥ 24
	<15	—	≥ 24 and < 30
ND	≥ 9	—	≥ 46

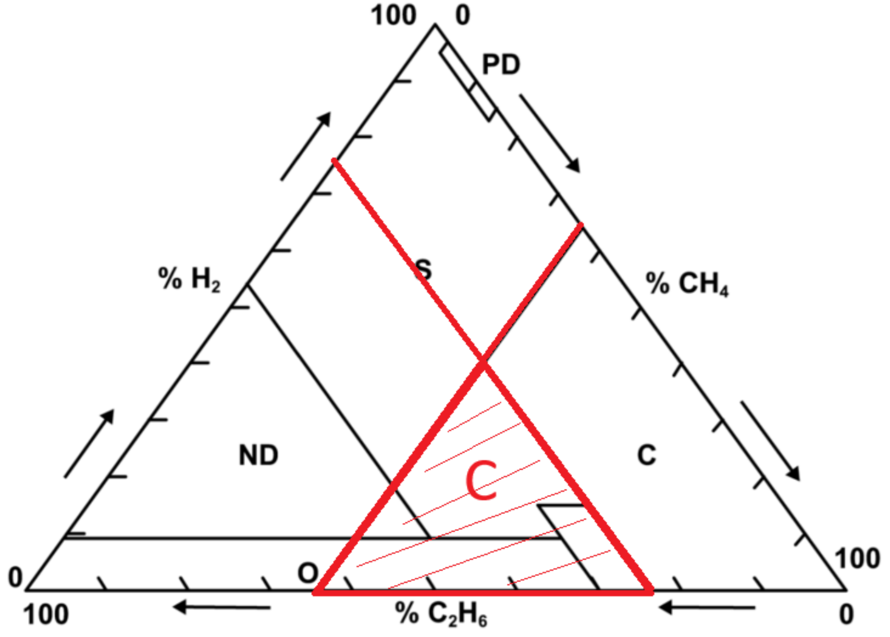


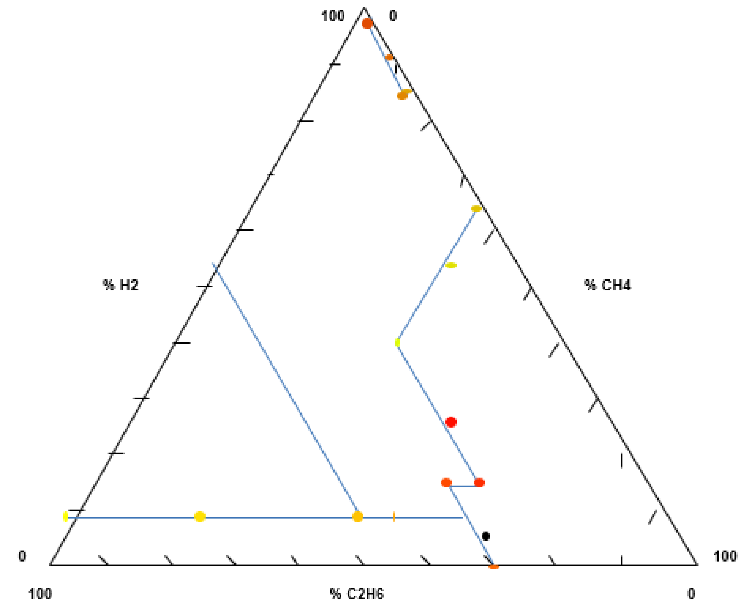
Figure D.3—Duval Triangle 4 method for low temperature faults

Section xx.xx – Toni Mellin

- Topic: Mistakes in Duval triangle 4 & 5
- Example 2

Triangle 4

Percent coordinates			Result	
H2	CH4	C2H6	Excel	IEEE
9	0	91	O	N/D
9	21	70	O	N/D
9	45	46	O	N/D
9	51	40	O	S
9	61	30	C	S
0	70	30	C	O
15	55	30	C	C/S
15	61	24	C	C/S
26	50	24	C	C/S
40	36	24	C	C/S
54	36	10	C	C/S
64	36	0	C	C/S
85	15	0	PD	S
84	15	1	PD	S
91	8	1	PD	S
97	2	1	PD	S



% H2	% CH4	% C2H6	Fault	Color	Date	Record No
9.0	0.0	91.0	O		29/06/2022 19:49	1
9.0	21.0	70.0	O		29/06/2022 19:49	2
9.0	45.0	46.0	O		29/06/2022 19:51	3
9.0	51.0	40.0	O		29/06/2022 19:51	4
9.0	61.0	30.0	C		29/06/2022 19:51	5
0.0	70.0	30.0	C		29/06/2022 19:52	6
15.0	55.0	30.0	C		29/06/2022 19:52	7
15.0	61.0	24.0	C		29/06/2022 19:52	8
26.0	50.0	24.0	C		29/06/2022 19:53	9
40.0	36.0	24.0	C		29/06/2022 19:53	10
54.0	36.0	10.0	C		29/06/2022 19:54	11
64.0	36.0	0.0	C		29/06/2022 19:54	12
85.0	15.0	0.0	PD		29/06/2022 19:54	13
84.0	15.0	1.0	PD		29/06/2022 19:54	14
91.0	8.0	1.0	PD		29/06/2022 19:55	15
97.0	2.0	1.0	PD		29/06/2022 19:55	16

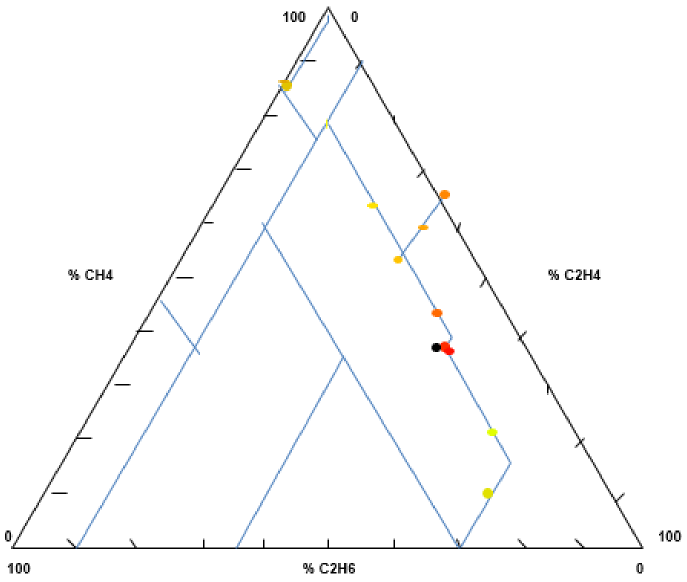
Section xx.xx – Toni Mellin

– Topic: Mistakes in Duval triangle 4 & 5

– Example 3

Triangle 5

Percent coordinates			Result	
CH4	C2H4	C2H6	Excel	IEEE
78	10	12	T2	C
63	25	12	T2	C
53	35	12	T2	C
59	35	6	T2	T3
65	35	0	T2	T3
43	45	12	T3	C
37	49	14	T3	C
36	50	14	T3	C
21	65	14	T3	C
10	70	20	C	T3
85	1	14	PD	S
86	0	14	PD	S
97	1	2	PD	O



% CH4	% C2H4	% C2H6	Fault	Color	Date	Record No.
78.0	10.0	12.0	T2		29/06/2022 19:56	1
63.0	25.0	12.0	T2		29/06/2022 19:56	2
53.0	35.0	12.0	T2		29/06/2022 19:56	3
59.0	35.0	6.0	T2		29/06/2022 19:57	4
65.0	35.0	0.0	T2		29/06/2022 19:57	5
43.0	45.0	12.0	T3		29/06/2022 19:57	6
37.0	49.0	14.0	T3		29/06/2022 19:59	8
36.0	50.0	14.0	T3		29/06/2022 20:00	9
21.0	65.0	14.0	T3		29/06/2022 20:01	10
10.0	70.0	20.0	C		29/06/2022 20:02	11
85.0	1.0	14.0	PD		29/06/2022 20:04	12
86.0	0.0	14.0	PD		29/06/2022 20:04	13
97.0	1.0	2.0	PD		29/06/2022 20:04	14

Section xx.xx – Toni Mellin

– Topic: Mistakes in Duval triangle 4 & 5

– Proposal to fix the mistakes

Triangle 4 changes:

	H2	CH4	C2H6
C (current IEEE)	-	≥36	≥24
C (fix)	-	≥36	<24
S (current IEEE)	≥9	-	≥ 30 and < 46
S (fix)	>9	-	> 30 and < 46
O (current IEEE)	<9		≥ 30
O (fix)	≤9		≥ 30
PD (current IEEE)	-	≥ 2 and < 15	< 1
PD (fix)	-	≥ 2 and ≤ 15	≤ 1
S (current IEEE)	-	< 36 and ≥ 15	< 1
S (fix)	-	< 36 and > 15	< 1

Triangle 5 changes:

	CH4	C2H4	C2H6
T2 (current IEEE)	-	≥ 10 and < 35	< 12
T2-H (fix)	-	≥ 10 and ≤ 35	≤ 12
C (current IEEE)	-	≥ 10 and < 50	≥ 12 and < 14
C (fix)	-	≥ 10 and < 50	> 12 and < 14
T3 (current IEEE)	-	≥ 35	< 12
T3-H (fix)	-	> 35	≤ 12
T3 (current IEEE)	-	≥ 50	≥ 12 and < 14
T3-H (fix)	-	≥ 50	≥ 12 and ≤ 14
C (current IEEE)	-	≥ 10 and < 70	≥ 14 and < 30
C (fix)	-	≥ 10 and ≤ 70	> 14 and < 30
T3 (current IEEE)	-	≥ 70	≥ 14
T3-H (fix)	-	> 70	≥ 14
S (current IEEE)	-	< 10	≥ 14 and < 54
S (fix)	-	< 10	> 15 and < 54
PD (current IEEE)	-	< 1	≥ 2 and < 14
PD (fix)	-	≤ 1	≥ 2 and ≤ 15
O (current IEEE)	-	≥ 1 and < 10	≥ 2 and < 14
O (fix)	-	> 1 and < 10	≥ 2 and < 15

Section xx.xx – Toni Mellin

- Topic: Duval triangle updates of (2020)
- Proposal to update Duval triangle methods as per 2020 updates from Dr. Michel Duval
  - Duval triangle 1, PD or T1 result -> Duval Triangle 4 analysis
    - T2 result from Duval triangle 1 no longer would recommend triangle 4 analysis
  - Duval triangle 5, T2 and T3 to be considered as T2-H & T3-H (thermal faults in oil only)

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When low energy or low temperature faults are identified using the Duval Triangle 1 (PD, T1 or T2), more information can be obtained with Duval Triangle 4.

When high, or very high, temperature faults have been identified with Duval Triangle 1 (T2 or T3), more information can be obtained using the Duval Triangle 5.

Section xx.xx – Toni Mellin

- Topic: Corrections to Duval pentagons 1 & 2 and arcing sub-faults of
- Small corrections were discussed in IEC 60599 maintenance group to Duval pentagons 1 & 2 to correct for potential graphical errors especially in the edges of the zones
- Adding distinction between arcing sub-fault types of discharges in oil (-H) and in paper (-P) is under consideration for Pentagon 2 (b) and Triangle 1 (b)

Limits of fault zones of Pentagon 1 in (x,y) cartesian coordinates

PD	(0, 33)	(-1, 33)	(-1, 24.5)	(0 ,24.5)	
D1	(0, 40)	(38.042, 12.361)	(32.061, -6.048)	(4, 16)	(0, 1.5)
D2	(4, 16)	(32.061, -6.048)	(24.204, -30.229)	(0, -3)	(0, 1.5)
T3	(0, -3)	(24.204, -30.229)	(23.511, -32.361)	(1.090, -32.361)	(-6, -4)
T2	(-6, -4)	(1.090, -32.361)	(-23.511, -32.361)		
T1	(-6, -4)	(-23.511, -32.361)	(-35.001, 3)	(0, -3)	(0, 1.5)
S	(0, 1.5)	(-35.001, 3)	(-38.042, 12.361)	(0, 40)	(0, 33)
	(0, 24.5)	(-1, 33)	(-1, 24.5)		

Example of Pentagon 1 changes

The numerical values of the (x, y) coordinates of zone boundaries in Pentagon 1 are indicated below [the dot of Figure D.1 is at coordinates (0,0) and the apex H2 is at coordinates (0, 40)][11]:

— PD: (0, 33), (–1, 33), (–1, 24.5), (0, 24.5);

— D1: (0, 40), (38, 12), (32, –6.1), (4, 16), (0, 1.5);

— D2: (4, 16), (32, –6.1), (24.3, –30), (0, –3), (0, 1.5);

— T3: (0, –3), (24.3, –30), (23.5, –32.4), (1, –32); (–6, –4);

— T2: (–6, –4), (1, –32.4), (–22.5, –32.4);

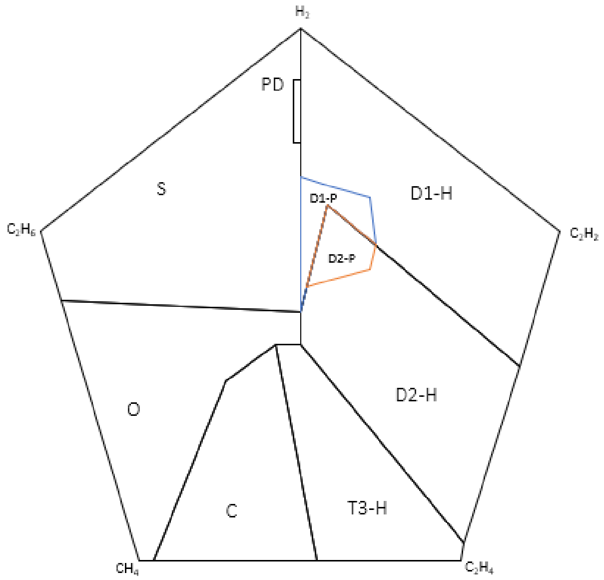
— T1: (–6, –4), (–22.5, –32.4), (–23.5, –32.4), (–35, 3), (0, 1.5); (0, –3);

— S: (0, 1.5), (–35, 3.1), (–38, 12.4), (0, 40), (0, 33), (–1, 33), (–1, 24.5), (0, 24.5);

IEEE C57.104-2019 Pentagon 1

Section xx.xx – Toni Mellin

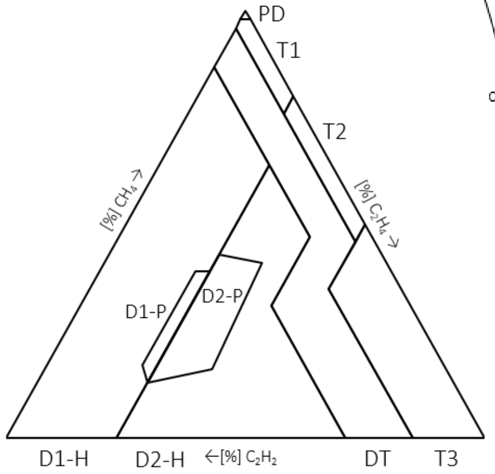
- Topic: Corrections to Duval pentagons 1 & 2 and arcing sub-faults of
- The WG could consider the applicability of these?



Key, by increasing order of severity of sub-types of faults.

Low	S	stray gassing of oil < 200°C
	PD	corona partial discharges in a gas phase
	O	overheating of paper or oil, *t* < 250 °C
	T3-H	hot spot in oil, *t* >700 °C
Moderate	D1-H	discharges of low energy D1 in oil, including sparking PDs
High	C	carbonization of paper, *t* > 300 °C,
	D2-H	discharges of high energy D2 in oil
Very high	D1-P	discharges of low energy D1 in paper, including sparking PDs
	D2-P	discharges of high energy D2 in paper

NOTES:
1-carbonization of paper between turns **C1,** of very high severity, occurs along the boundaries between zone O and the upper parts of zones C and T3-H of Pentagon 2 of coordinates (0, -3), (-3.5, -3) and (-11, -8).
2-Heavy coking of oil on hot metals, of moderate severity, occurs in zone C.



Section xx.xx – Toni Mellin

- Topic: Collecting data and analysing DGA monitor data methods with CIGRE
- CIGRE working group A2/D1.67 "Guideline for Online Dissolved Gas Analysis Monitoring" is in the process of starting data collection and data analysis for continuous online DGA monitoring data, this has been discussed to be done with IEEE collaboration
- Many members of the WG also members in C57.104
- Could we work together with the CIGRE WG for collection and analysis of the data? Sharing the results with both groups and drawing conclusions separately?

Section *New*– Zack Draper

- Topic: Oil Preservation types

- O2 & N2 clearly affects the DGA statistics. But the association of O2 & N2 gas concentrations or ratios with the actual oil preservation type is somewhat weak (due to lack of data).
- To address the problem, we need an industry guideline for how to classify major classes of oil preservation systems (similar to cooling systems or LTCs) to properly categorize the DGA data. Future revisions of C57.104 will hopefully benefit from data being more clearly labeled by using such a scheme.
- Even if we manage to collect the current data available, no guidance has been given as to what certain common terms actually mean, hence data is often mis-classified (e.g. “Gas-Sealed” vs “Gas-Blanket”) or under-classified (just “Conservator”).

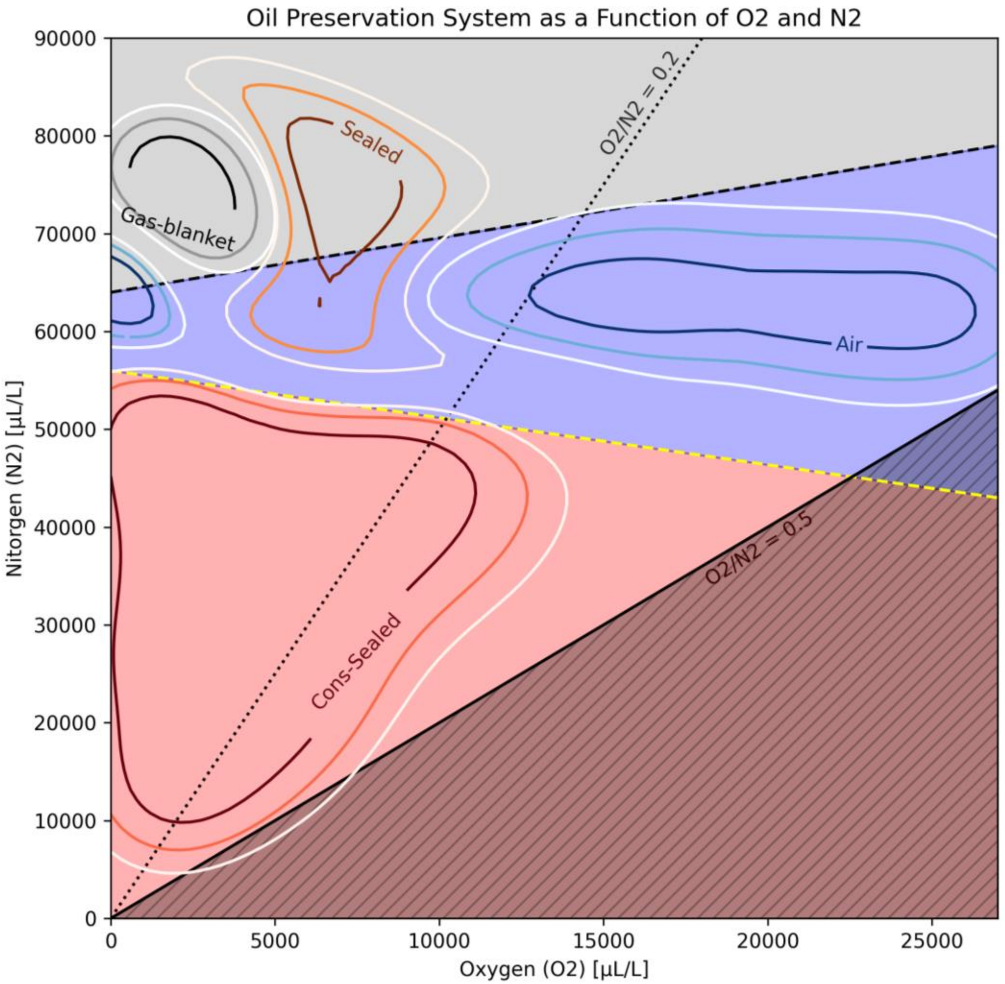
A Proposed Classification Scheme

A	Air-breathing		
C	Conservator		
	B	Bladder/Diaphragm, physical membrane	
	F	Free-Breathing	
G	Gas used in headspace		
	R	Regulated, positive pressure	
	S	Sealed volume of gas expansion, pressure relief valve	
	H	Hermetically sealed	
		D	Dessicant
		N	No Dessicant

For example: **AD =** air breathing with desiccant, **CBN =** Conservator with a bladder, no desiccant, **CFD** = Conservator, free-breathing with desiccant

please provide additional input

O2 & N2 Diagram



Regions of O2 and N2 gas concentrations where a labeled oil preservation system is most likely to be found (generated from labeled data).

Gas-blanket systems (N2, positive pressure regulated) have the lowest percentiles in gas concentrations and yet are classified as "sealed" by a low O2/N2 ratio.

IEEE Class	CH_4 90th	CH_4 95th	IEEE CH_4 90th	IEEE CH_4 95th	CO 90th	CO 95th	IEEE CO 90th	IEEE CO 95th
$O_2/N_2 > 0.2$	12	26	20	50	466	592	500	600
$O_2/N_2 \leq 0.2$	94	146	90	150	721	887	900	1100

Oil Preservation Class	O_2/N_2 Median	CH_4 90th	CH_4 95th	IEEE CH_4 90th	IEEE CH_4 95th	CO 90th	CO 95th	IEEE CO 90th	IEEE CO 95th
Air	0.220	73	120	20	50	684	862	500	600
Sealed	0.085	38	80	90	150	709	874	900	1100
Conservator Sealed	0.076	114	163	90	150	770	927	900	1100
Gas-Blanket	0.019	39	66	90	150	249	380	900	1100

Reference: Draper & Dukarm, CIGRE Canada, 2024, no. 768, zhdraper@deltaxresearch.com

Section 6.1.2.4 – Zack Draper

– Topic: Adding a 4th status code

– The 2019 revision dropped a 4th status level compared to the 2008 version. 2019 provides room for an “extreme DGA”, but has no specific guidance on what gas limits should be used.

– Overall result of C57.104-2019, is that many IEEE status code 3 are triggered (nearly 1 out of 3 transformers) and transformer owners left wondering what is actually “extreme” or not.

– In a study comparing DGA interpretation results on failure cases, just multiplying all of the 2019 status code 3 limits by a factor of 7 to 10 was a reasonable way to quickly add an additional status code level without changing much logic of the current guide.

– See “How to Improve IEEE C57.104-2019 DGA Fault Severity Interpretation” Draper, Dukarm and Beauchemin. IEEE/PES T&D, 2022

Andrew Larison - Proposal for Additional Language in C57.12.104 IEEE Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers

Points for Consideration

- Manufacturing processes for high volume distribution transformers and power transformers can differ in several ways. These include processes such as robotic welding, tank top construction, and the point at which the tank top is secured to the tank.
- The samples considered in determining DGA starting points were predominantly power transformers. There is no differentiation between the acceptable “factory new” DGA levels for distribution and power transformers.
- DGA tests are not routine but are a special test for distribution transformers per C57.12.00. However, many customers, with the number increasing in the past decade, request DGA tests at the factory to have a starting point for monitoring through the life of their distribution class transformers (this includes most commonly industrial and alt energy type applications).
- The main objective of DGA testing is to monitor a **change** in the gas levels, which are indicative of internal failures/breakdowns in the transformer during operation.

Andrew Larison - Proposal for Additional Language in C57.12.104 IEEE Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers

I think the following statement would be appropriate in C57.104 as a note to tables 1-4 or in section 6.1.3 following tables 1-4.

For distribution transformers, post test manufacturing processes that include welding may introduce small amounts of acetylene into the oil which are not due to internal failures. Users should consult with the manufacturer for an evaluation of the source of the gas and to determine acceptable starting DGA levels for monitoring. These levels shall be based on the processes and manufacturing history of the factory.

Table 4—95th percentile values from multi-points (3-6 points) rate analysis of laboratory DGA samples with all gas levels below Table 1 values, in µL/L/year (ppm/year)

		Maximum µL/L/year (ppm/year) rate in function of the period between first and last point of the laboratory DGA series (3 to 6 samples)			
		O_2/N_2 Ratio ≤ 0.2		O_2/N_2 Ratio > 0.2	
		Period between first and last point of the series			
		4-9 Months	10-24 Months	4-9 Months	10-24 Months
Gas	Hydrogen (H_2)	50	20	25	10
	Methane (CH_4)	15	10	4	3
	Ethane (C_2H_6)	15	9	3	2
	Ethylene (C_2H_4)	10	7	7	5
	Acetylene (C_2H_2)	Any increasing rate		Any increasing rate	
	Carbon monoxide (CO)	200	100	100	80
	Carbon dioxide (CO_2)	1750	1000	1000	800

NOTE—Contribution of voltage class, MVA, and volume of mineral oil in the unit was not studied for Table 4 as they have not been retained for Table 1 and Table 2. Data was insufficient to study age influence.

See 5.4 for general considerations on the selection of norm values.

See Annex A for a description of the methodology used to produce the numbers provided in Table 1, Table 2, Table 3, and Table 4.

Approved Actions from Last Meeting

1. Motion was made by Emilio Morales-Cruz and seconded by Matt Chu to create a task force to investigate (*on line monitoring*) to potentially include in this guide, create a new guide, or publish a white paper.
2. Lance Leward made a motion (seconded by Stuart Chambers) that this (*artificial neural networks*) should be rolled into the earlier approved TF about online monitoring. This motion was approved.
3. Ramsis Girgis made a motion (seconded by Evgenii Ermakov) to write and submit text (for H2 CH4 generation) to the WG for inclusion in the guide.
4. Tim Raymond made a motion (Adrina S Cisco seconded) for the WG chair to begin a discussion with IEEE for the creation of an anonymized DGA mineral oil database.

Gas Generation caused by Moderately heated Transformer Cores

- Background to the recognition of this gas Generation mechanism
- Cause and specifics of this gas generation mechanism
- Characteristics of this gas generation mechanism
- Impact of the hydrogen gas generation associated with this gas generation mechanism
- Reducing the impact of this gas generation mechanism
- Impact of the recognition of this gas generation mechanism on the IEEE Standards and customer Specifications

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Annex

Annex A (informative) Data research and findings
A.1 Data collection and preparation
A.2 Dataset characteristics
A.3 Future work

Annex B (informative) DGA data—Evaluating the rate of gas level change
B.1 Impact of DGA limitations on the selection and use of rate norms
B.2 Example 1
B.3 Example 2
B.4 Example 3
B.5 General application

Annex C (informative) Typical faults
C.1 The six basic types of faults
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Annex D (informative) Fault identification methods
D.1 Key Gas method
D.2 Doernenburg Ratios method
D.3 Duval Pentagon 1 method
D.4 Duval Triangles 1, 4 and 5 methods
D.5 Duval Pentagon 2 method
D.6 Mixtures of faults
D.7 When to use the Duval Pentagons and Triangles
D.8 Interpretation of CO and CO_2
D.9 Other useful gas ratios for fault identification

Annex E (informative) Case studies
E.1 Unintentional core ground
E.2 LV connections issues
E.3 Internal transformer arcing causes relay protective action
E.4 De-energized tap changer (DETC) high resistance connection
E.5 Broken connector on fuse holder

Annex F (informative) Evaluation of fault severity—alternative method

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Annex G (informative) Historical material
G.1 (4) General theory
G.2 (6.3) Determining the gas space and dissolved gas-in-oil equivalents
G.3 (6.5.1) Determining the transformer condition and operating procedure utilizing TCG in the gas space
G.4 (6.7.1) Evaluation of possible fault type by the Doernenburg Ratio method
G.5 (7) Instruments for detecting and determining the amount of dissolved gases present

Annex H (informative) Bibliography
H.1 Gas evolution
H.2 Detection and interpretation

New text - Gas Generation by thin oil film between moderately heated Laminations of Transformer Cores

This gas generation mechanism was originally recognized when it was reported by a user of Large Power Transformers of moderate generation of hydrogen gas in six same design large power transformers with generation rates ranging from 0.5 to 3.5 parts per million (ppm) per day and an H_2/CH_4 ratio of 6 – 8. Other gases, and mainly CO and CO_2, were generated at a low rate.

Subsequent factory and laboratory investigations showed that this gas generation phenomenon was caused by moderately overheated cores with core hot spot temperatures in the 120 – 160 ºC range. Therefore, this core gassing occurs under a certain combination of core excitation, ambient temperature, and loading conditions. The rate of generation of Hydrogen is typically in the range of 2.5 – 3.2 PPM / day during the summer months.

Further investigations showed that the thin oil film between the electrical steel laminations facilitates a chemical reaction where hydrogen atoms of the hydrocarbon chain of the oil are loosely aligned to the steel surface and then released as hydrogen molecules. This reaction occurs at relatively lower temperatures compared to when hydrogen is produced by bulk oil at temperatures of several hundred degrees. The background of this gas generation mechanism is presented in References 1 – 4 below.

New text - Gas Generation by thin oil film between moderately heated Laminations of Transformer Cores

It is, however, to be recognized that the impact of hydrogen gas generation due to this phenomenon is not in itself harmful to the transformer. It is only that this hydrogen generation over a period of time could reach a high accumulation that could mask otherwise detrimental hydrogen generation due to other phenomena such as partial discharge and high temperature metal overheating of bulk oil. For this reason, it is advisable that when a transformer is experiencing hydrogen generation due to core overheating that the oil is de-gassed periodically and actions taken to change the core excitation (Tap position) and / or providing additional cooling of the transformer oil.

As a result of the recognition of this phenomenon, the industry has seen an increased significance of developing accurate calculation of the core hot spot temperature. Also, industry standards are being revised to recognize this phenomenon and a 140°C limit for core hot spot temperature is now recommended in the IEEE Loading Guide presently gives a maximum limit of 140 C for the core hot spot temperature Also, some users of power transformers include in their Power Transformers specifications a limit of 130 C on the maximum value of the core hot spot under worst conditions of load, ambient temperature, and core over-excitation.

New text - Gas Generation by thin oil film between moderately heated Laminations of Transformer Cores

References to add to Annex H - Bibliography

T. V. Oommen, R. A. Ronnau and R. S. Girgis, “New Mechanism Of Moderate Hydrogen Gas Generation In Oil-Filled Transformers”, CIGRE Conference Paper 12-206, Paris Meeting, Aug-Sep 1998.

T.V. Oommen, R.S. Girgis, R.A. Ronnau, “Hydrogen Generation from Some Oil-Immersed Cores of Large Power Transformers”, Minutes of Sixty-Fifth International Conference of Doble Clients, 1998, Section 8-8

Ed G. teNyenhuis, Günther F. Mechler, Ramsis S. Girgis and Gang Zhou, Calculation of Core Hot-Spot Temperature in Power and Distribution Transformers”, IEEE Transactions on Power Delivery, Volume 17, Issue 4, Oct. 2002 Pages 991 – 995.

Ramsis S. Girgis and Ed teNyenhuis: “Gas Generation due to moderately overheated cores”, Presented at the IEEE PES Conference, July 2009, Calgary, Canada

New Business

Adjournment