There are several layers of understanding and mastering the knowledge that can also be applied to DGA expertise

ABSTRACT

DGA plays a vital role in the diagnostics and maintenance of the transformers. It is a multidisciplinary and complex field that is not easy to master. That is the reason why this article is oriented to explaining the learning and understanding the process associated with DGA.

KEYWORDS

basics, DGA, diagnostics, gasses, oil, principles

Basic principles of DGA - Part I

Learning, using, and creating your own view on DGA

Introduction

The importance of dissolved gas analysis (DGA) for transformer maintenance is, of course, very well known and already appreciated by the whole industry and the of Transformers Magazine readers.

The three previous articles [1 - 3] describe in detail the development of DGA through the ages and some future scenarios. Also, they described how DGA obtained the role of a first and most crucial test for general transformer health. As a by-product of those facts and knowledge, the readers may study some basic principles related to transformer design, materials, exploitation, and the DGA technique.

The knowledge presented and described in the three articles was based on chemical principles, electrical principle, and 30 years of experience performing that test along with all the related activities from sampling to post-mortem inspections and, of course, brainstorming at DGA Working Groups. The knowledge has been presented from a user's perspective and contains field, laboratory, and active expert's interaction with minimum commercial bias.

However, acquiring knowledge is definitely not enough for anybody to use and apply for an organisation's or their personal benefit. This topic has been well known in education science as Bloom's taxonomy introduced in 1956 and revised in 2001. It is one of the most well-known frameworks for classifying educational goals, objectives, and standards, and it is practically synonymous with the cognitive domain.

From the pyramid, Fig. 1, adapted to DGA education target, the readers may follow their progress in comprehending the DGA related knowledge. Most existent offline and online training courses and webinars are limited to acquiring and remembering the knowledge without offering the attendee the self-capability to apply it by a real experiment. Understanding the already solved cases is not sufficient to be able to confront new situations with a transformer with new technologies and materials.

The real-life situation is that the attendee will try to apply the same principles in his / her unresolved cases, and in most cases at the beginning, he / she will misuse them. Of course, if the engineer is persevering and the transformer owner has enough patience, after several cases and having gained enough experience, the fresh engineer will be capable of becoming an experienced DGA operator. Proper education may significantly reduce the cost of knowledge gained by experience.

In contrast to the previous articles, this one is more oriented to explain learning, understanding, knowledge, and beyond. It intends to explain to the young and middle-aged generation the difference of being able to do things by themselves compared to using an external advisor or using outsourced diagnostics. The pros and cons of outsourcing the diagnosis system will be intensively explained. As a preview, it can be stated that using an international standard or guides and models is the most plausible way to attribute a transformer the condition to a statistical value of concept that may not match your specific equipment.

After understanding this matter, the readers will have the chance to experience all the six stages of Bloom's taxonomy adapted to DGA. This unbiased knowledge and compression permit being much more independent in finding the adequate path for them to preserve the best transformer condition and minimise unpleasant surprises related to it.

This articles that will follow and the Q&A report [4] will summarise the basic principles of DGA.

Correlation between transformer failures DGA and all other unimportant phenomena

A fundamental concept that will be present through the article is the correlation and understanding of essential interrelations between faults and failures. The focus will be on the most critical ones and the modality to prevent them by discrimination from less critical types.

A transformer may develop a failure without developing any gases (30 % of the cases).

The vice versa is also true – dissolved gases may appear even in large concentrations without any faulty condition (30 % of the cases).

Fig. 2 illustrates one of the circumstances of transformer malfunction without any preceding signs in the DGA tests.

In approximately 10 % of the cases, the time between gas apparition and failure is measured in less than milliseconds. In those circumstances, no DGA method can detect the phenomena before it occurs, not even the fastest and best-located DGA device. The only device based on

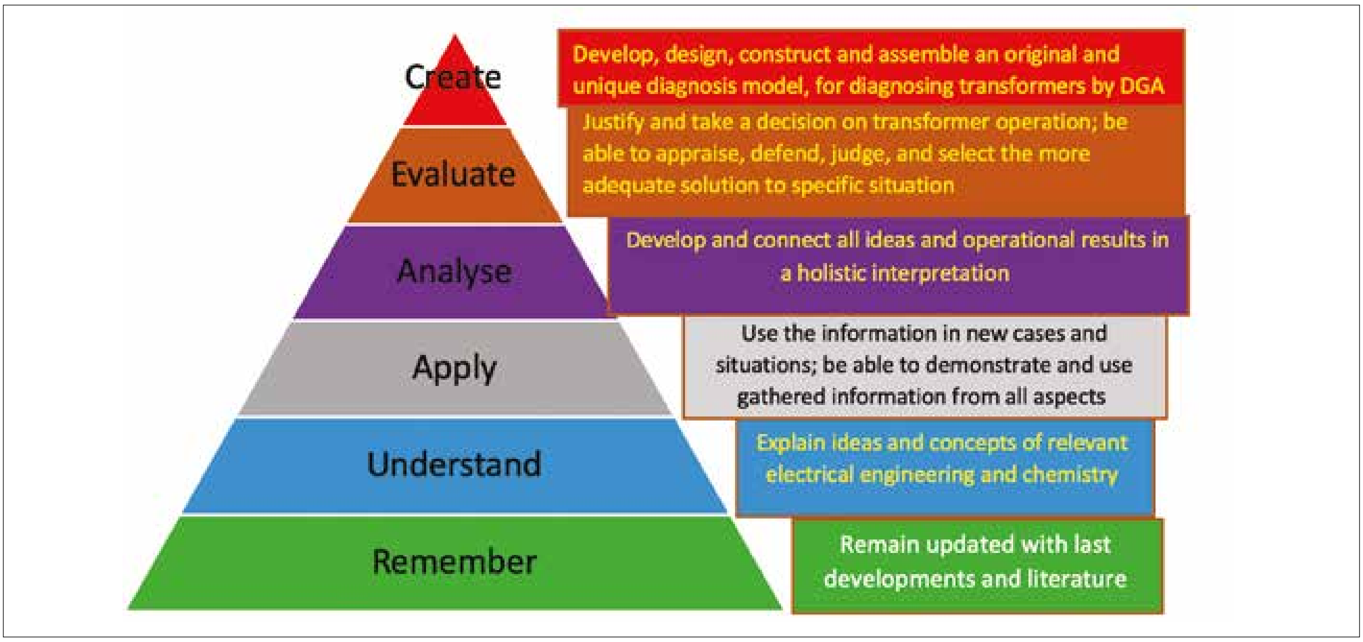


Figure 1. Bloom's taxonomy adapted to becoming a transformer DGA expert

Although some types of failures may occur very rapidly, most of them may be predicted and prevented by electrical and chemical tests and by adequate following of the maintenance procedures

dissolved gas principles is the Buchholz relay. Other electrical protection relays may have the opportunity to trigger the transformer, in real time as well.

Although those types of failures occur very rapidly, most of them may be predicted and prevented by most of the electrical and chemical tests and adequately followed maintenance procedures. Assuming they are implemented properly, the knowledge and technologies today allow for further reductions of any unplanned outages. The conditions for reducing the overall transformer failure rate in the future are as follows: abate the usage of off-shelf health indexes, including DGA, on behalf of tailor-made calculation adapted for the specific user and his transformer, and the general fleet maintenance approach.

Understanding this matter, the reader will be able to better distinguish and understand when a potential gas pattern is something irrelevant, or when the same gas pattern may be a signal for an important phenomenon with potentially catastrophic consequences.

More and more utilities around the world are now adopting outsourced and non-involved diagnosis conclusions from a multinational source. The user should realise that the price for those services is paid mainly by taking too much extra-precaution measures and trying to solve nonessential occurrences. The overall cost for such an attitude for a medium fleet may even be higher than one or more transformer failures. And the worst thing for maintenance engineers may be the loss of credibility for DGA. Multiple false alarms should be avoided as well as catastrophic failures. They both have negative consequences.

Fig. 4 shows that in most transformer failures, the direct correlation between critical physical faults and the anomalous dissolved gas apparition is not valid.

Some failures are not able to be detected by any presently known tests, but most of them may only be prevented a long time in advance. Those subjects will not be described further in this article, some of them have already been covered by pre-

Figure 2. Transformer critical failure without any DGA signal alarm

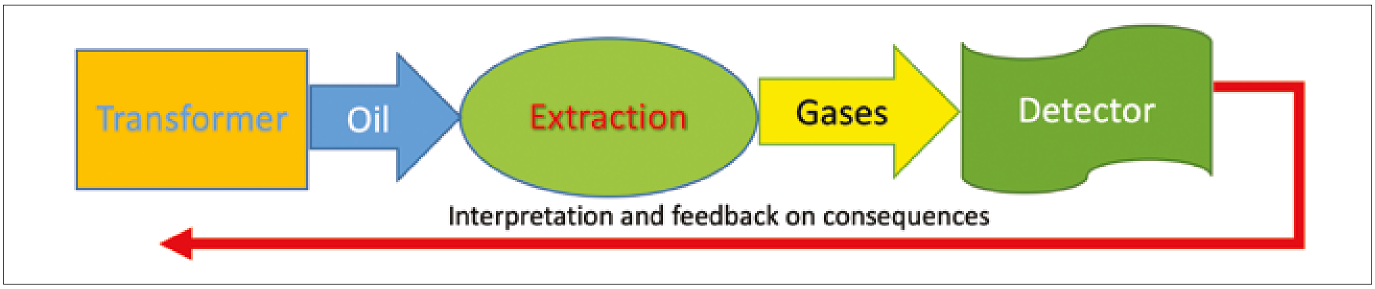


Figure 3. Compulsory stages for DGA, including the portable and all types of online devices

vious articles [5], and hopefully will be a topic of one of the future articles.

Each time a transformer is repaired or inspected after any findings from any tests, the user and the diagnosis team that recommend the intervention should ask a straightforward question: Was this action caused by the tests or was the alarm indeed 100 % justified?

However, the answer here is quite complicated and partially depends on the experience and knowledge of the team involved. Since DGA seems to be arriving in our era to become the most informative test for power transformers, those deliberations are mainly focused on DGA. The following articles will reflect on real justified and unjustified specimens of abnormal DGA versus abnormal phenomena inside the transformer.

Basic principles of DGA include the four compulsory phases that need to be performed in a laboratory, or by a portable or an online device:

- Sampling – the most crucial stage for the correct evaluation
- Extraction of the gases from the oil – very tricky
- Measurement, evaluation, calcula-

DGA expert understands when a potential gas pattern is something irrelevant, or when the same gas pattern indicates an important phenomenon with potentially catastrophic consequences

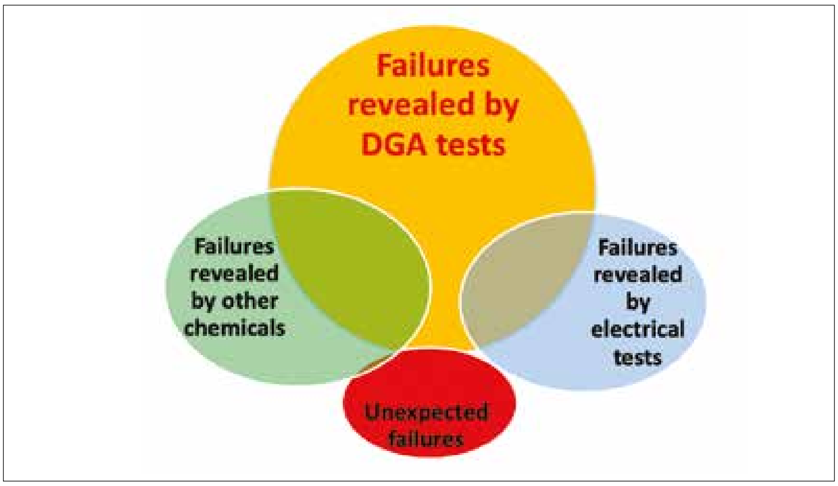


Figure 4. General concepts of the correlations between different measurement types and preventing failure probability for insulating power transformers

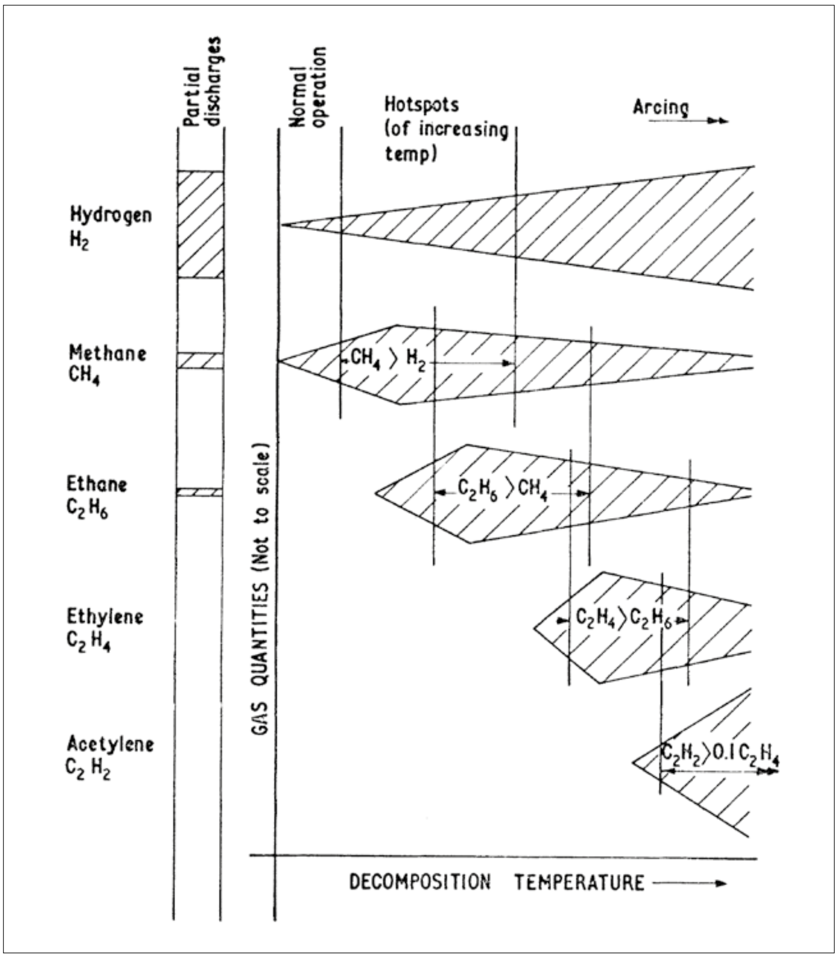
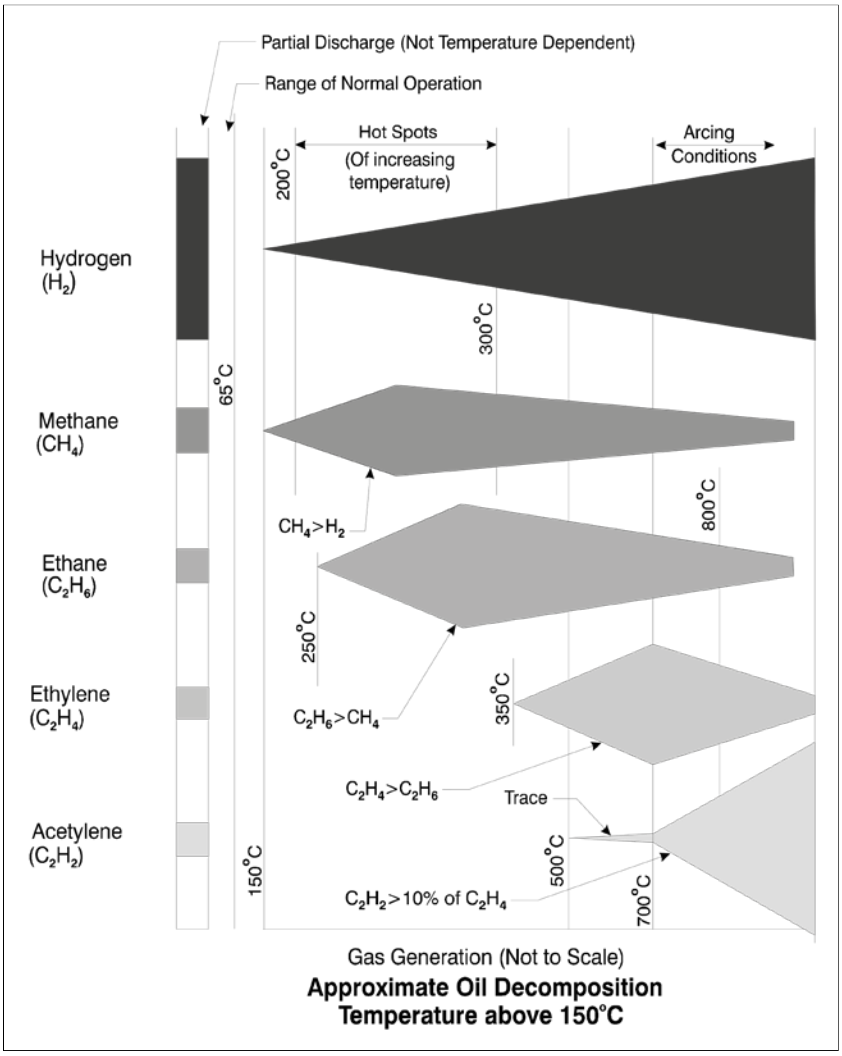
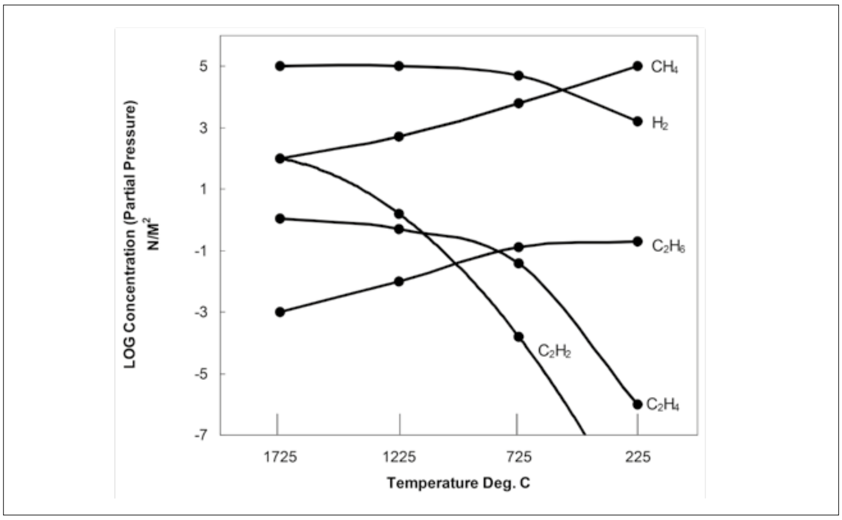


Figure 5. Incorrect thermodynamic models, especially for hydrogen productions from insulating oils
a) Comparison rates of evolution of gases from oil as a function of decomposition energy [6]



b) Combustible gas generation vs approximate oil decomposition temperature [7]



c) Halstead's thermal equilibrium partial pressures [8]

tion of the correct concentration – many options
- Interpretation and feedback on the consequences.

This paragraph focuses on recent publications on DGA subjects and their correlations to real-life situations.

- Thermodynamic model

The most common thermodynamic models that were used until the last publication of the standard IEEE C57.104 are shown in Fig. 5.

A correct version of the hydrogen gases formation from all oil (liquids) insulating is shown in Fig. 6.

Specific thermodynamic theory for each oil type molecule is much more satisfactory also by practice and real findings. The essential factor that emerges from that new description is the incorrect assumption that hydrogen is a gas that evolves from the insulation materials at all the temperatures and cases. Some also claim that its concentration in oil is directly proportional to temperature. As may easily be seen from the attached diagrams from the last version of IEEE, this gas-only appears at two extremes temperatures and situations:

- Partial discharges at relatively low temperature where hydrogen loses the covalent bonds to the hydrocarbons chain by specific electron energy
- Arcing at a very high temperature when hydrogen is disconnected from the hydrocarbon chain to form the unsaturated energetic triple bonds of acetylene and the hydrogen atoms released in this chemical mechanism is the formation of hydrogen molecules.

In the other two most widespread failure modes, when oil and cellulose are at low to medium heating, hydrogen is only a negligible gas.

Those factors have become significant when a user needs to select the proper online gas detector. The manufacturers of any DGA online devices have to explain correctly and unaffectedly the expectations and limitations of such online devices. The main misconception of online hydrogen devices is the fact that they can detect all abnormal DGA cases without pointing out a specific failure.

A more broad and detailed description and explanation of the complete thermodynamic model for oil decomposition is described by Shirai et al. [10].

The physical and chemical principles of the above-mentioned models will be debated and described in the following articles adapted for a non-chemist electrical professional.

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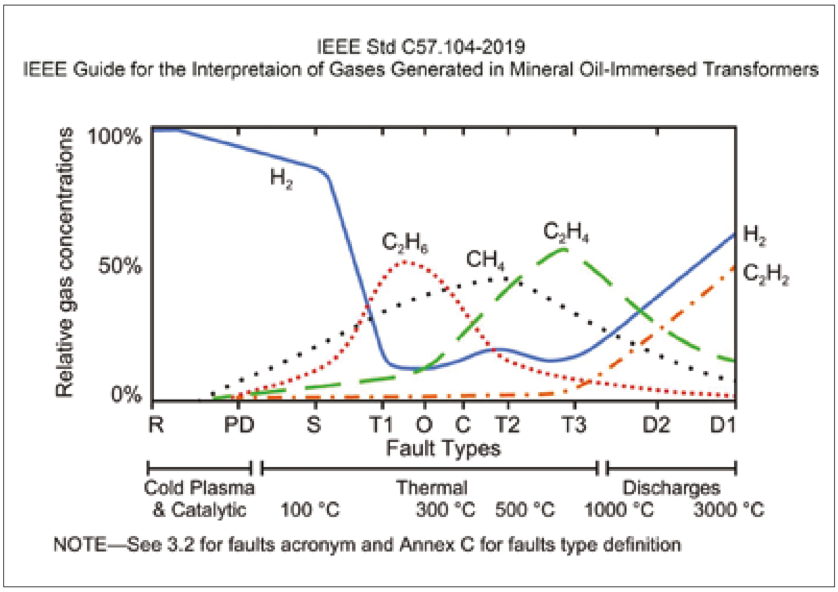
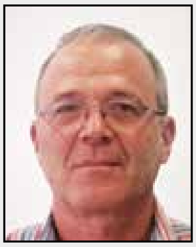


Figure 6. Relative percentage of dissolved gas concentration in mineral oil as a function of temperature and fault type [9]

Author



Marius Grisaru has a MSc in Electro-Analytical Chemistry from the Israel Institute of Technology. He has almost 30 years of intense experience in almost all transformer oil test chains, from planning, sampling and diagnosis to recommendations and treatments, mainly in Israel but also in other parts of the world. He is responsible for establishing test strategies and procedures, and for creating the acceptance criteria for insulating liquids and materials, based on current standardisation and field experience. He trains and educates electrical staff on insulating matrix issues from a chemical point of view. He is an active member of relevant Working Groups of IEC, CIGRE, and a former member of ASTM. He is also the author and co-author of many papers, CIGRE brochures, and presentations at prestigious international conferences on insulation oil tests, focusing on DGA, analytical chemistry of insulating oil, and advantageous maintenance policy for oil and new transformers.

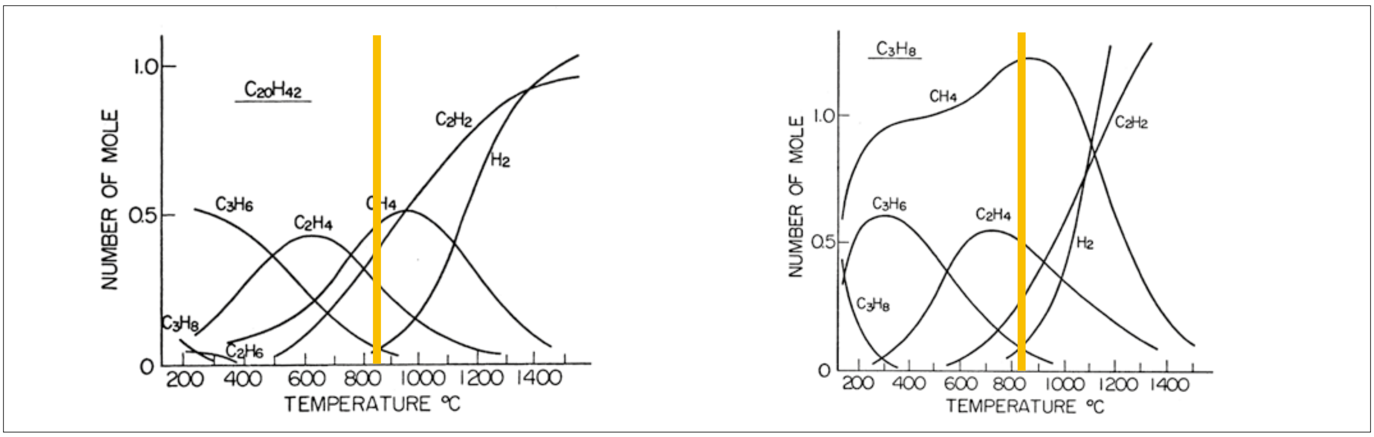


Figure 7. Different oil molecules break into different gases at the same temperature [10]