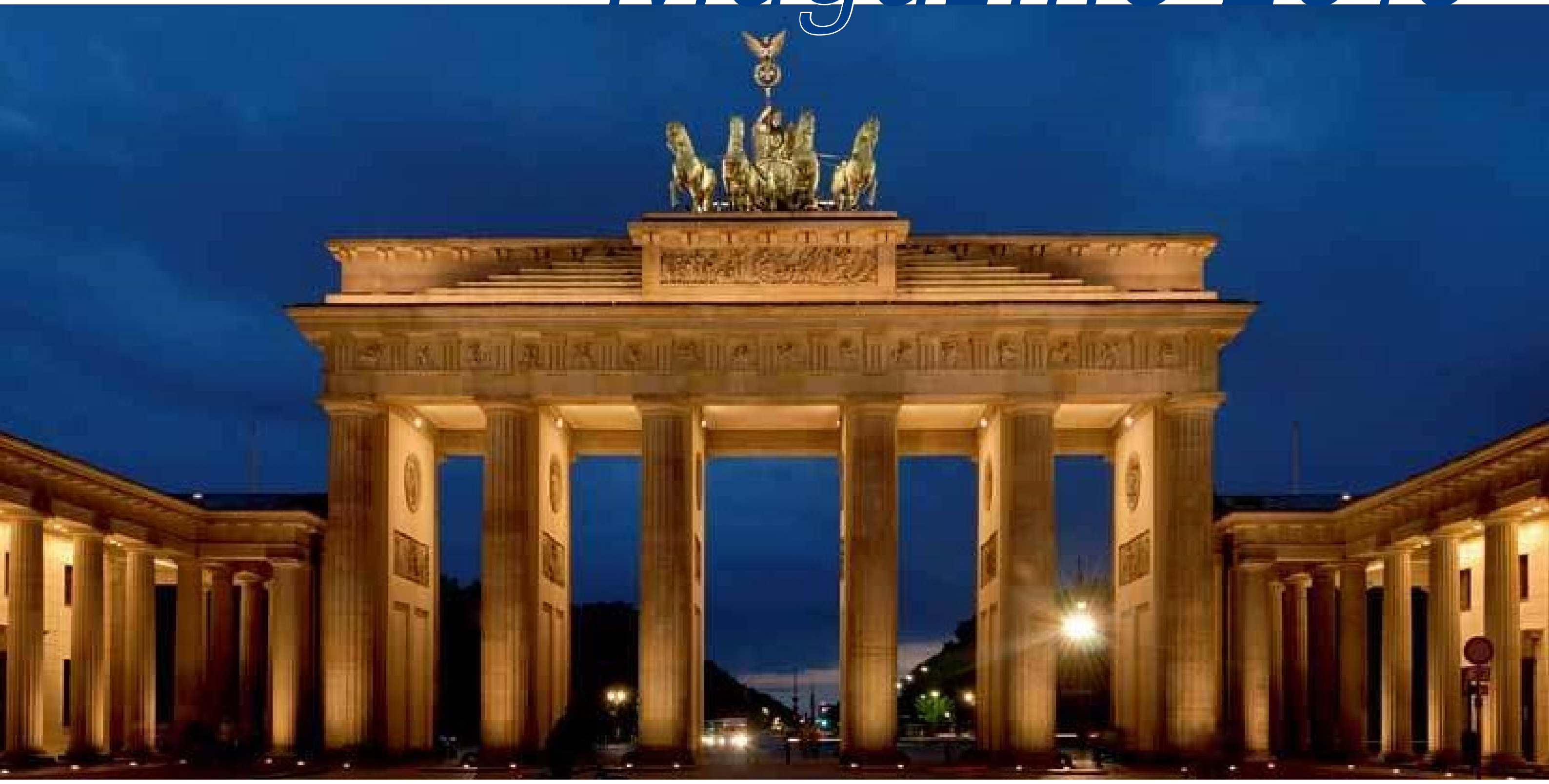
for the installers and operators of explosion protected electrical installations

# Magazine 2010



STAHL

# Classification of Hazardous Areas

## Standard, Theory and Practice

by Estellito Rangel Jr.

When designing electrical installations for an industry that works with flammable substances, it is necessary to know where the classified locations are. These locations are identified in area classification drawings. This information will then help to specify the special electrical and electronic equipment for each hazardous area, and will also help with the elaboration of safety procedures for plant operation and maintenance.

Area classification is an engineering study for analyzing and classifying the environment where explosive atmospheres may occur.

The international standards that guide zone classification studies are:
IEC 60079-10-1 for flammable gas and vapour atmospheres, and IEC 60079-10-2 for dusty environments.
This article will show difficulties and points that need to be taken into consideration when performing this engineering study using the IEC 60079-10-1 standard as a basis.

### Frequency and duration of occurrence of explosive atmospheres

Hazardous areas are classified into zones based on an assessment of the frequency of occurrence and duration of an explosive gas atmosphere. The definitions found in IEC 60079-10-1 are:

- Explosive atmosphere: mixture with air, under atmospheric conditions, flammable substances in the form of gas, vapour, dust, fibers, or flyings which, after ignition, permits self-sustaining propagation;
- Zone 0:
  an area in which an explosive gas atmosphere is continuously present, for long periods or frequently;
- Zone 1:
  an area in which an explosive gas atmosphere is likely to occur in normal operation occasionally;
- Zone 2:
  area in which an explosive gas atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

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One can say that some terms like ›long period‹, ›short period‹ and ›likely‹ are not clearly defined. The existing note at clause 3.8 warns that: ›indications of the frequency of the occurrence and duration may be taken from codes relating to specific industries or applications‹.

Various attempts have tried to set time limits for these definitions, but none have been officially adopted. The most known values used as reference are:

- Zone 0:
  occurrence of explosive atmosphere for more than 1000 h/yr
- Zone 1:
  occurrence of explosive atmosphere for more than 10, but less than 1000 h/yr
- Zone 2:
  occurrence of explosive atmosphere for less than 10 h/yr.

Note from the editorial staff: These values originate from a study of the British Petroleum Industry and are discussed controversially among experts.

Taking into account that in many industrial plants it is not common practice to install gas detectors in open areas, an eventual leak can last for more than 10 hours before it is detected. The full period of time from when the leak starts until it is fixed must be taken into consideration. Depending on availability of maintenance teams, more than ten hours will probably have passed by this point. So, if these time intervals are applied without care when classifying locations, many locations would be classified as zone 1. Perhaps this is one reason why these intervals are not yet accepted and included in the international standards.

An industrial plant with locations where leaks achieving concentrations above the lower explosive limit – LEL are expected to happen 10 h/year, every year, is probably a poorly maintained unit.

## The extent of zones

The extent of the zone depends on the estimated or calculated distance over which an explosive atmosphere exists before it disperses to a concentration in air below its lower explosive limit LEL – with an appropriate safety factor.

Regarding gases and vapours, the greater the release rate, the larger the extent of the zone. The release rate itself depends on other parameters, namely

- Geometry of the source of release
- Release velocity
- Concentration
- Volatility of a flammable liquid
- Liquid temperature

The size of a cloud mixture of flammable gas or vapour with air and the time for which it persists after release halts can be influenced by means of ventilation.

The effectiveness of the ventilation in controlling dispersion and persistence of the explosive gas atmosphere will depend upon the degree and availability of ventilation and the design of the ventilation system. For example, ventilation may not be sufficient to prevent the formation of an explosive gas atmosphere but may be sufficient to avoid its persistence.

Three degrees of ventilation are recognized in IEC 60079-10-1: high, medium and low. The assessment of the required degree of ventilation first requires the knowledge of the maximum release rate of gas or vapour at the source of release, either by verified experience, reasonable calculation, sound assumptions or available manufacturer's data.

The IEC 60079-10-1 shows in Annex B a method for estimation of hypothetical volume $V_Z$, which represents the volume over which the mean concentration of flammable gas or vapour will typically be either 0,25 or 0,5 times the LEL, depending on the value of a safety factor, k. It is important to note that the calculation of $V_Z$ is only intended to assist in assessing the required degree of ventilation.

The standard emphasizes that the hypothetical volume is not directly related to the size of the hazardous area, and stresses that for detailed recommendations regarding the extent of the hazardous areas in specific industries or applications, reference may be made to national or industry codes relating to those applications.

In its Annex C, some examples of hazardous area classification are given, but they represent guidance only and will need to be adapted so as to take into account particular circumstances.

It is necessary to consider that there are some codes where we can find examples and figures of classified areas, but these do not include any information on how those distances were found, or even the characteristics of the locations. Some experts say that such distances were defined through a purely qualitative approach, and that there appears to be no scientific basis for the distance determination.

## Mathematical models to assess hazardous areas

To evaluate the volume of an explosive atmosphere that is formed after a leak, some mathematical models are used. This is a complex task, because many variables are involved.

The most important parameter in defining the source of a gas leak is its mass release rate. This can be easily computed based on the known upstream temperature and pressure. The method used depends on whether the release is subsonic or choked. Choked releases are sonic at the point of release. As for practice, the released and ambient gases are assumed to behave as ideal gases.
In some cases, small leaks are defined in the IEC 60079-10-1 as giving rise to flammable gas clouds of ›negligible extent‹ (NE). This NE criteria is based on the concept of a gas cloud volume, denoted ›$V_Z$‹, which has a mean concentration of 50 % of the LEL. In cases where the $V_Z$ is less than 0,1 m$^3$, for secondary sources, the releases are classified as being of negligible extent. The IEC standard contains a methodology for the estimation of this cloud size which is of unknown origin and dubious accuracy, but the essential concept of NE is clear.

Having established the definition of Vz and the methodology for its calculation for indoors and subsequent application to zone classification, IEC 60079-10-1 includes a methodology for the estimation of Vz for outdoor applications in B.5.2.3. It is based on indoor methodology and therefore requires an approximation of the room size and ventilation rate that might be regarded as equivalent to outdoor situations. Such approximations are inevitably arbitrary. An example is given with a hypothetical cube with side dimensions of 15 m and a wind speed of 0.5 m/s. There is no basis for the choice of this value of space volume. A wind speed of 0,5 m/s is often used in generic hazard calculations. The standard correctly emphasizes that results using this methodology and these example values of room volume and wind speed will be conservative, but nevertheless they are often used in the absence of any guidance.

Some recently published studies have analyzed the extent of classified areas using the IEC 60079-10-1 formulae, using Computational Fluid Dynamics – CFD, aiming to put the zone extents in a quantitative approach.

The size of the gas clouds obtained from CFD simulations were compared to those obtained from the IEC 60079-10-1, which presents simple formulae for estimating gas cloud volumes.

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| LEL [Vol %] | M [kg/kmol] | LEL [kg/m$^3$] | Release rate [g/s] | Safety factor k | Ambient temp [°K] | $(dV/dt)_{min}$ [m$^3$/s] | Volume $V_Z$ [m$^3$] | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | f = 1 | f = 5 |
| 4,4 | 16 | 0,0293 | 5,42 | 0,5 | 293 | 0,370 | 12,34 | 61,69 |

Table 1: Example for a calculation of methane/ air mixture according to IEC 60079-10-1 (f = quality factor of the ventilation efficiency)

One can say that a standard may not be the right place to define equations, because each situation requires a different model. Relevant software, technical books and papers present more detailed mathematical models for many situations. The objective of a standard should be focused on defining the procedures and minimal parameters that need to be considered when elaborating the area classification study. Thus, the duty for selecting and applying adequate equations is the responsiblity of a team of experts for the study. It is not the standard's duty to define the equations to be used, especially when so many situations and variables may take place.

Table 1 illustrates the results of a $V_Z$-calculation for an area hazardous by methane.

The quality factor f characterizes the efficiency of ventilation ranging from f=1 (ideal condition) to f = 5 (impeded air flow)
In table 2 the results using CFD and IEC 60079-10-1 calculation methods are compared considering methane at 50% LEL, with the following leak conditions: pressure = 5,0 bar and hole size = 5,0 $mm^2$.

The results from the CFD simulations indicate that the gas cloud volumes specified according to the ›$V_Z$ criteria‹, may be overestimated for low pressure releases in open areas using the IEC 60079-10-1 formulae. The $V_Z$ gas cloud volumes calculated using CFD were up to three orders of magnitude smaller than those estimated by IEC 60079-10-1. For the methane case considered, all the gas cloud volumes are smaller than those defined as being of ›negligible extent‹, i.e. 0,1 $m^3$.

| **$V_Z$ using CFD** | **$V_Z$ using IEC 60079-10-1** |
|---|---|
| 0,0936 | 12,3 – 61,7 |

Table 2: $V_z$ [$m^3$] volume comparison with the following conditions: concentration of methane at 50% LEL, leakage: pressure = 5,0 bar hole size = 5,0 $mm^2$

Some papers also bring comparisons between IEC 60069-10-1 and CFD models for hydrogen. They concluded that due to hydrogen's high diffusion rate and buoyancy, the calculations in IEC 60079-10-1 are conservative and can result in inaccurate combustible volumes for hydrogen. In these publications a selection of probable maximum hydrogen vent rates and leak rates from piping connections and equipment, combined with ventilation conditions were considered, that were modeled and then compared to the hypothetical flammable volume calculations for the conditions referenced in IEC 60079-10-1. For the majority of scenarios, the CFD modeling for hydrogen could greatly relax the existing codes and standards.
As a comparison, for a given mass leak rate, hydrogen would form an 8x larger flammable cloud than methane, as the cloud size is determined by the flow in mole per second, rather than flow in kg/s. This illustrates in a definite way, that it is not correct, in area classification studies to use a single ›typical‹ figure, even for similar processes, without considering the substances' properties.
This clearly has implications in terms of the current practice of hazardous area classification.

## Figures of area classifications

It is recommended that area classification is undertaken in such a way that the various steps which lead to the final extents definitions are properly documented.
All relevant information used should be referred to, as:

- recommendations from relevant codes and standards;
- gas and vapour dispersion characteristics and calculations;
- a study of ventilation characteristics in relation to flammable material release parameters so that the effectiveness of the ventilation can be evaluated.

The visualization of classified areas is helpful to electrical equipment engineers and installers, and therefore, the zone classification drawings are also included in the documentation, showing each part of the plant identified regarding its zone, explosion group and temperature class, taking into account the properties of the flammable materials that are present.

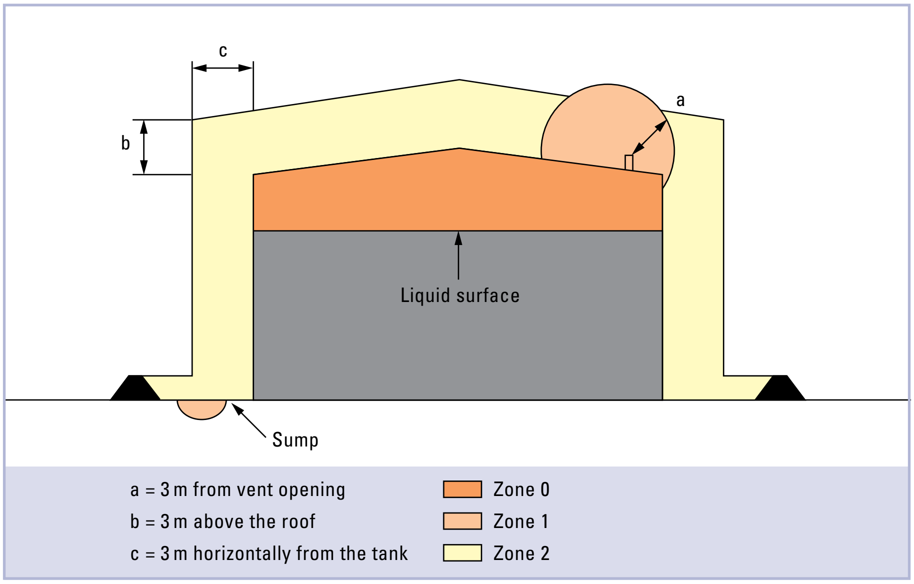

Figure 1: Example no. 8 of IEC 60069-10-1, flammable liquid storage tank, situated outdoor, with fixed roof

Although IEC 60079-10-1 has some figures as examples of area classification, in each one, some but not all of the parameters which influence the type and extent of zones are given, while some factors have been specified, and still others have been identified but not quantified.

In arriving at the distances shown in the figures, specific plant component conditions have been given. The leakage conditions have been considered in relation to the mechanical performance of the equipment and other representative design criteria. They are not intended for general application, because factors such as inventory of process material, shut-off time, dispersion time, pressure and temperature affect the area classification and need to be applied to the particular problem being considered. Thus, these examples are for guidance only and need to be adapted so as to take particular circumstances into account.

This information probably means that those figures are not precise, and consequently, they cannot be reproduced in all studies by a simple ›copy and paste‹ action.

An example about care when analyzing such figures can be seen in figure 1, in a flammable liquid storage tank situated outdoors with fixed roof, as shown in the Annex C-example no. 8. Only one source of release is shown – the vent opening – and it is defined as having a zone 1 area around it. Other sources of release may be present in the field, as flanged connections, but these are not indicated in the figure. If an abnormal overfilling happens, a zone 2 area is expected to appear around the tank, as indicated.

One can note that the figure also indicates the sump as zone 1. Considering that a zone 1 is by definition as a location where the explosive atmosphere is likely to occur in normal operation, (and that this process runs under atmospheric pressure), at first sight it seems contradictory that the sump is classified as zone 1, especially since an explosive atmosphere inside the sump is only possible as an aftermath of the tank overfilling or as a leak in a flange connection (secondary sources of release). The justification for this classification of zone 1 is related with the effects of ventilation, as detailed in Annex B.7 – Table B.1, where it is foreseen that a secondary source of release can generate zone 1 areas if the ventilation degree is low. This is admissible in closed locations, but it is not clear if it can also be applied in an open outdoor area that has good ventilation availability, as defined for this example no. 8.

Another relevant observation is that the extents given by that figure don´t seem to be trustworthy, because based on natural ventilation, it is very difficult for an explosive atmosphere to form outdoors, and neither the tank dimensions, nor the release rate through the vent, are defined. For a further distance around the tank at the base level, and for a distance above the ground, vapour is only likely to appear if there is a major spillage, which is considered abnormal. Additionally, the prevailing wind will influence the size of the surrounding zone 2, and so, it is not possible to guarantee the distances shown in this example no. 8 for all situations regarding liquid storage tanks, independently from the stored substance.

Figure 2 illustrates this statement, as the same storage condition, different zones and distances were defined by a particular code, without any information on installations dimensions or ventilation characteristics.

Each flammable substance has properties which need to be considered when classifying areas.Therefore, it is not possible to apply a single ›typical‹ figure to all flammable substances and situations.

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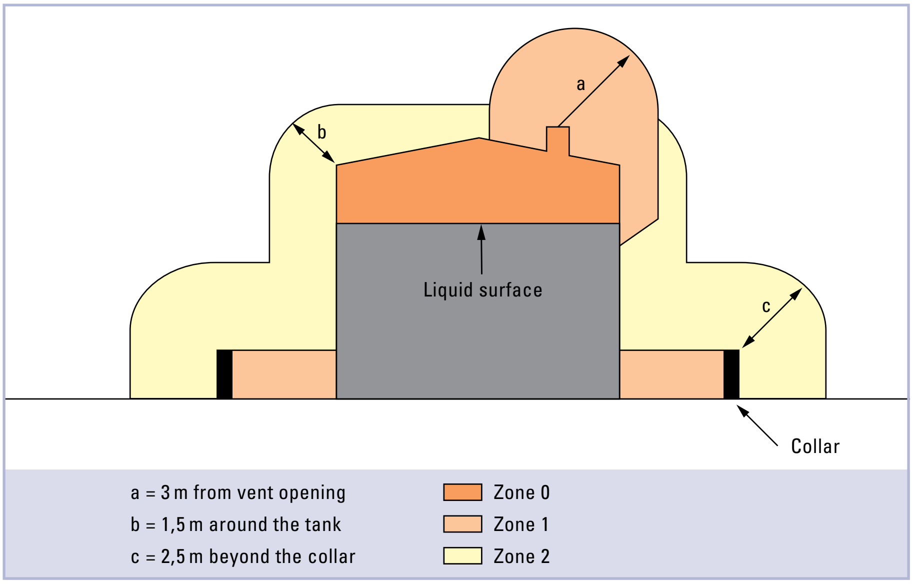

Figure 2: Area classification for storage tanks, by a particular code

## Considerations to explosion risks

Explosion protection is of particular importance to safety. Whereas explosions endanger the lives and health of workers as a result of the uncontrolled effects of flame and pressure, the presence of noxious reaction products and consumption of the oxygen in the ambient air that workers need to breathe.

In Europe, the ATEX Directive 1999/92/EC emphasized that ignition risks are not limited by electrical equipment, and so, it is necessary to take into account non-electrical sources of ignition to elaborate the ›Explosion Protection Document‹. This document includes the identification of the hazards, the assessment of explosion risks, and the definition of the specific measures to be taken for improving the health and safety protection of workers potentially at risk from explosive atmospheres.

Nowadays there are commercial softwares specifically developed to estimate explosion scenarios. It is important to note here that the ignition consequences can vary greatly depending on environment characteristics. As an example, the immediate ignition of hydrogen releases leads to different consequences of delayed ignition. Immediate ignition will lead to jet fires for continuous leaks and fireballs for rupture, whereas delayed ignition of a continuous or instantaneous leak leads to a flash fire or deflagration. IEC 60079-10-1 introduced an apparently antagonistic statement in the clause 4.2; as it says in the second paragraph that ›in situations where an explosive gas atmosphere has a high likelihood of occurring, reliance is placed on using equipment which has a low likelihood of creating a source of ignition. Conversely, where the likelihood of an explosive gas atmosphere occurring is reduced, equipment constructed with less rigorous requirements may be used.‹ This enforces the objective of avoiding explosions, harmonized with the requirements of the ATEX Directive. But surprisingly, in the third paragraph, it is found that ›a risk assessment may be carried out to assess whether the consequences of ignition of an explosive atmosphere requires the use of equipment of a higher equipment protection level (EPL) or may justify the use of equipment with a lower EPL than normally required‹.

If a ›normally required EPL‹ is the minimum measure to comply with ATEX 1999/92/EC Annex II A 2. - Explosion protection measures 2.5 ›All necessary measures must be taken to ensure that the workplace, work equipment and any associated connecting device made available to workers have been designed, constructed, assembled and installed, and are maintained and operated, in such a way as to minimize the risks of an explosion and …‹, an alternative to use a ›lower EPL‹ sounds like an ignition can be permitted, which can be interpreted as an enhanced danger to workers and to the environment. As no orientation is given in IEC 60079-10-1 on establishing the basis to perform an explosion risk assessment, and considering that this can be quite difficult when the boundary of an installation has varying risks of ignition, such verification can only be carried out by competent persons in the field of explosion protection based on their experience and/or professional training. In Germany and several other countries a ›competent person‹ must be recognized by a government authority.

## Conclusions

Developing mathematical models representing gas dispersion is not a simple task, and if getting a nearly thermodynamic modulation is desired, one never reaches a conclusion, particularly because the parameters are not stable.

The IEC 60079-10-1 is a standard in its evolutionary stage, but considering that area classification is closely related to thermodynamics and fluid dynamics, the ISO may be the more adequate environment for it to grow, as opposed to the IEC, because electrical engineers do not usually have a technical background on ventilation requirements and gas or physical properties.

The area classification study can not be the duty of a single person, and definitively is not a matter of just ›applying equations‹. Beyond the understanding of the relevance and significance of properties of flammable substances, it is necessary to get information about the system behavior from professionals who are familiar with the processes and equipment, including safety, electrical, mechanical and other qualified engineering personnel who have the expertise to know exactly which considerations are applied to each situation. This is enforced by the fact that although many codes have figures to orient the shape of the foreseen explosive atmosphere, such figures are not ›universally applicable‹, because for each facility there are many factors that affect the extent of zones.

It is expected that if IEC 60079-10-1 could be moved to ISO, this would enable it to receive collaboration from specialists in gas dispersions, thermodynamics and fluid dynamics, allowing the standard to achieve a mature stage, helping professionals get more precise guidance for performing area classification engineering studies. In particular this concerns the standards for non-electrical equipment.

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