Fire Safety Guidance Note FSGN 63

Guidance on the Installation of Fast, Rapid and Super Vehicle Charging Units

Recommended standard for the installation of fast & rapid charging units within City of London Corporation enclosed structures.

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1. Introduction

1.1 In May 2019, the City of London Corporation (CoL) adopted a transport strategy with ambitious proposals to improve air quality by encouraging the switch to zero emission vehicles. In order to achieve this CoL has started and will continue to build infrastructure for charging electric vehicles, both private and commercial, and invest its own larger electric vehicle fleet.

2 Aim

2.1 The aim of this note is to provide guidance on the safe installation of fast /rapid/super charging points (See Appendix 1 for charging rates) within CoL structures such as. multi storey car parks (Both above ground and subterranean). It is hoped that the standards outlined below will be applied at all new installations and so far as is reasonably practicable, applied at all existing installations.

3 Methodology to produce the guidance

3.1 A range of external documents have been accessed to complete this guidance including scientific documents and legislation (Appendix 2). A University of Newcastle research paper on lithium ion battery fires; a 2019 HSE webinar on electric vehicles; The Institution of Engineering and Technology 3rd edition code of practice for electric vehicle charging equipment installation; GLA London's Electric Vehicle Infrastructure Delivery Plan; TFL London's electric vehicle charge point installation guidance and Protection Association risk control document RC59 were found to be most pertinent. Various YouTube videos on electric vehicle fires and Lithium ion battery fires were examined to assist with consequence and impact determinations. Enquiries were made of Schneider -electric, manufactures of vehicle charging stations, City of London Police Cyber Crime Unit and RSA Insurance Group. On the 22nd January 2020, a half day electric vehicle charging workshop was hosted by the Property Safety Team with representation from the London Fire Brigade, City of London Police and CoL staff including electrical engineers and building control officers.

4 Legislation

4.1 There is no specific UK legislation covering the installation, design and operation of workplace vehicle charging areas. However, general duties under the Health and Safety at Work etc. Act 1974 and Regulatory Reform (Fire Safety) Order 2005 do apply as will specific elements of the Electricity at Work Regulations 1989 , Control of Substances Hazardous to Health Regulations 2002, Workplace Health, Safety and Welfare Regulations 1992 and Management of Health and Safety at Work Regulations 1999; in particular the need to undertake a risk assessment.

5 Lithium Ion Batteries

5.1 Lithium ion battery (LIB) is a proven technology for automotive industry. lithium ion batteries are rechargeable energy storage devices where lithium ions move between the anode and cathode, which are electrically separated by a membrane. All components are fully soaked in an electrolyte. During charging, lithium ions move from the cathode towards the anode and in the discharge cycle the ions travel back. The electrons move via the external electrical circuit and lithium ions and solvent molecules travel within the electrolyte[4].

5.2 In conventional lithium ion batteries with liquid electrolytes, there are five key components: anode, cathode, separator, current collectors, and electrolyte[5]. A relatively high number of materials have been used in cathodes, including lithium manganese oxide (LMO), lithium cobalt oxide (LCO), lithium nickel cobalt aluminium oxide (NCA), lithium nickel manganese cobalt oxide (NMC) or olivine type materials, such as lithium iron phosphate (LFP). The latter has appeared as one of the safest chemistries due to its thermal stability and non-toxicity[4]. Carbon is commonly used as an anode in lithium ion batteries.

5.3 Electrolytes used in lithium ion batteries are often highly flammable. The most used electrolytes are mixtures of various carbonates (e.g. propylene carbonate) and a dissolved salt (e.g. lithium hexafluorophosphate (LiPF6))[4].

5.4 Research in lithium ion battery has escalated and has produced many refinements in terms of efficiency, energy density, flexibility, etc., however considering recent incidents with electric vehicles the focus is now shifting towards the safety of electric vehicles.

5.5 Hazards can occur during the normal operation of the battery or during conditions or events outside its normal operating range. These include electrolyte/material spillage if individual cell casings are damaged, the battery's reaction to high external temperatures and fire, and short circuiting, over-voltage and voltage reversal.

6 Battery hazards:

6.1 Battery hazards to be avoided include:

- thermal events - rapid temperature changes can result in significant thermal expansion of components in batteries. The mechanical stress and/or different material expansions caused by this temperature changes may potentially influence battery integrity or internal electrical connections.
- thermal runaway - In thermal runaway events an exothermic reaction can occur and the battery heats up to over 600°C in a matter of seconds. This results in the electrolytes inside the cells disintegrating into simpler, more flammable molecules, such as methane, ethane, and hydrogen gas. The cathode also starts to decompose and release oxygen. These gases result in pressure and temperature build-up inside the battery, and eventually, an explosion[1].

- mechanical damage to batteries - can cause chemical reactions such as thermal runaway resulting in fire or explosion.
- overcharging - Overcharging a battery can cause a rise in battery temperature, swelling due to vaporising electrolyte or even fire or explosion through loss of containment and release of gases to outside atmosphere.
- gasses emitted from batteries - Overcharge, short circuit, the presence of an external heat source, etc. can cause sudden increases in temperature of the cell, leading to vaporisation of electrolyte. The venting mechanism is an important safety feature widely implemented for automotive batteries, however, when the gas is released from the battery it needs to be vented safely.
- electric shock – The voltages used in electric vehicles are potentially very dangerous. Voltages in a traditional car will typically be between 12V and 24V. In electric vehicles this can be up to 650V.

7 Hazards associated with charging

7.1 In addition to the risks from lithium ion batteries the are several other hazards connected with the activity of charging electric vehicles within a building structure. These include:

- unsuitable charging units or their incorrect installation
- the non-containment of a battery fire placing other vehicles or even the building structure at risk
- inability to quickly isolate electrical supplies to battery charging units in the event of an emergency
- inability of alarm systems or sprinkler systems to respond rapidly to an electric vehicle fire
- mechanical damage to the charging unit
- water, flammables or combustibles present in the area where charging is taking place
- incorrect charging leads being used
- inadequate lighting in the area
- environmental contamination- surfaces and drainage systems that cannot deal effectively with the consequences of battery leakage or battery fire/explosion.
- electromagnetic forces (This may or may not be a hazard further information is required)
- hacking of electric vehicles or charging points

8 Guidance standards

8.1 The standards listed below aim to control or remove several of the hazards linked with lithium ion batteries and the charging of electric vehicles. They should be reviewed by anyone involved in the installation or control of fast, rapid or super electric vehicle charging facilities within CoL building structures and wherever possible adopted in full.

8.2 Structural standards

Installation are to: -

- comply with Building Regulations in particular Approved Document B comply with British Standard BS7346: Part 7: 2013.Design of car park ventilation systems for a fire condition,
- where practical, provide 2-hour fire rating of charging areas floors, ceilings and side walls
- ensure charging bays have a minimum of 1200mm to the front of bay, space around sides of 900mm to 1200mm in addition to the standard vehicle bay of 2400mm x 4800mm. Please see example in: Diagram 1 [page 10].

Relaxation of bay widths may be possible when bays include compartment side walls of 2 hour fire rating construction (Please see Photo 1 [page 11]) However, please note that the equalities requirement still needs to be considered and reference should be made to Building Regulations Approved Document M, Access to and use of buildings
- ensure that charging units are to be protected from mechanical damage.
- incorporate surfaces that are impermeable to battery and battery fire contaminants and facilitate easy cleaning following an incident

No offices or occupancy space (temporary or otherwise) within or the building structure where charging is to be undertaken is to be provided unless it is fire rated to 60 minutes.

8.3 Ventilation standards

Whilst natural ventilation may provide adequate air changes for the normal building structure use, it is considered insufficient in a lithium ion battery fire situation. Therefore, mechanical ventilation should always be provided.
An engineer design should be commissioned to calculate the exact number of air changes required in an electric vehicle fire situation, but it is anticipated that this is unlikely to be less than 14 air changes per hour. Cyclone or jet fans provided to boost ventilation to the required maximum levels in fire situations, should be activated by a sprinkler flow switch and or manual override switch. Trigger of boost ventilation by activation detectors or fire alarm may also be possible provided there is not a risk of the sprinkler system failing to operate due to heat or smoke being removed from sprinkler activation heads. An advanced ventilation system may be able to incorporate two stages of boost such as increasing the number of air changes to 10 per hour on activation of the fire alarm system and to full required extraction capacity on activation of sprinklers or manual switch.

Suggested Computer Fluid Dynamic (CFD) modelling parameters include:

- 200 Celsius at 2000mm height
- heat output of 16 Mega Watts at 10 minutes
- a minimum of 10 air changes per hour to support fire fighting

To assist arriving firefighting, ventilation units should be designed, where possible, to afford the best protection for firefighters from known or protected entry routes. Also to assist firefighting, consideration can also to be given to using existing features within buildings: Photo 2 [page 11] shows stall boards offering street level access to ventilation in bays; Photo 1 [page 11] shows the internal view.

It may be advantageous to position charging bays near to naturally ventilated areas or close to final mechanical discharge routes to help prevent/reduce contaminants spread within building, however this will need to be carefully balance with other considerations in this document such as protecting evacuation routes.

Ventilation design solutions must not jeopardise protect escape routes such as stairwells and all products of combustion must be discharged to a safe area such as above the height of the building or away from openings.

Charging units in normal use must be adequately ventilated to ensure safe use and longevity of components. Manufactures advice should be followed and care taken during installation to ensure that vents remain clear.

8.4 Electrical standards

Electrical installations

Electrical installations are to comply with:

- Electricity at Work Regulations
- British Standard BS 7671:2018 Requirements for Electrical Installations. IET Wiring Regulation (18th Edition)
- IET Code of Practice and Guidance notes for electric vehicle charging (Currently HSR25 and ISBN:184919839X respectively)

Vehicle charging units should have their own dedicated electrical supply so that a fault or fire does not interrupt other electric services to the building. The cables should be low smoke halogen free (LSHF) flexible cabling manufactured to EN 50525-3-11 and where possible, encased in metal trunking, steel conduit and or underground ducting. These steps will help to protect evacuees and fire fighters should a fire occur involving the units or their supply.

A TT earthing exclusion zone of 2500mm is to be enforced from other earthing zones and consideration should also be given to protecting charging circuits with RCBO/RCD Type B safety devices.

It is recommended that ventilation systems have dual power supplies to ensure that they are resilient in most fire situations and charging areas are to be adequately illuminated so that people using the chargers can do so without risk.

Vehicle leads

Without providing and maintaining charging leads there is a risk that unregulated poor-quality varieties could be used increasing the risks of fire, electrocution and possibly cyber-crime. It is, therefore, recommended that lead(s) of suitable length are provided at each charging unit. Where the type of vehicle to be charge may vary it is suggested that two industry standard leads are to be attached to the charging unit, which are either tethered or retractable. One cable should be fitted with a CCS combo 2 connector and other with a CHAdeMO connector allowing for the charging of most vehicles on the UK market.

Isolation of electrical supplies to charging units

Emergency isolation of the charging points is to be provided. Manually operated isolation switches should be strategically located, for example at primary entrances and or manned kiosks. Activation of the fire alarm or sprinkler must also isolate electrical supplies to all vehicle charging units in the vicinity of the fire. (If sprinklers were to operate whilst a vehicle is still being charged there may be an increased risk of electric shock to those in the area)

All isolation switches are to be clearly marked with “on/off” service positions. These markings should be readable in low light conditions to aid staff on site and fire fighters. In addition, power circuits are to be configured for manual resetting to protect emergency crews and maintenance operatives. Ideally the emergency isolation switch should also incorporate a “lock out key” to prevent unauthorised reinstatement.

Vehicle charging units

Charging units are to prevent over charging by allowing only 80% charge within a lithium-ion battery. They are also not to operate if the vehicles engine management systems have ascertained the battery is irate and may become unstable e.g. when less than 50 charges are left in the cells.

8.5 Facilities to support fire service

Building structures housing vehicle charging units are to ensure that their fire brigade information boxes contain details to the as built vehicle charging system including location of units and manual isolation switches.

Where charging units are in basements or large metal beam structures consideration should also be given to fitting simple communications systems for fire service use e.g. leaky feeder (radiating cable) cabling.

Where, so far as reasonably practicable, a down comer - dry falling main should be installed to feed any sublevels with electric vehicle chargers, regards of depth/level of the charging area from ground floor.

8.6 Security standards

Security experts are expressing concerns of the hacking on charging infrastructure. According to security analyst Ofer Shezaf enterprising hackers could gain access to smart electric vehicle chargers and obtain access to logins, payments, hack into city or utility systems that run the chargers or shut down parts of the network themselves. In some cases, hackers could potentially unlock a charge point with a key, plug in an Ethernet cable and browse away with a laptop in the same way one might talk to a Wi-Fi router on a home network.
The hackers can stop the charging processor of the EV charger and at the extreme end take down parts of charging network, in similar way hackers have taken down important businesses by overwhelming them with bogus network traffic[20]. The hackers can also set the charging points to the maximum end. The power overload can bring down the network or even cause a potential fire[21].

Due to these risk commissioning officers should check that the charging units have been designed to prevent hacking. Consideration could be given to restricting access to charging units to known individuals or placing them under security CCTV.

Also, the control of charging is to be undertaken by the charging unit at source and not by the vehicles engine management system or charging leads.

8.7 Sprinkler and fire detection systems

<u>Automatic sprinkler systems</u>

Due to the location of battery compartments in vehicles and the way unstable lithium ion batteries burn it is very unlikely that a ceiling mounted sprinkler system would extinguish an electric vehicle battery fire. Floor mounted sprinkler heads were considered but discounted due to the risk of mechanical damage and interference. It was, therefore, concluded in this guidance that sprinklers systems should be installed in the most effective way as to limit the spread of fire especially between neighbouring vehicles rather that tackle any vehicle fire.

It is recommended that automatic sprinkler systems in electric vehicle charging areas are:

- designed to meet BS EN 12845: 2015 and the Fire Protection Association's LPC automatic sprinkler installation rules
- designed to include either conventional sprinklers, deluge (20 heads) or multi jets (4 heads). If multi jets are selected these should be activated either by fire alarm or by sprinkler heads trip bulb

- installed to discharge between vehicles in order to offer greater protection against fire spread
- fitted so that the space between sprinkler heads is no more than 2000mm unless varied by sprinkler engineer's assessment and design
- fitted with sprinkler bulbs that operate at 57 degrees Celsius (Lithium Ion Batteries are believed to become unstable at 70 degrees Celsius, so it is important to try and get the sprinklers to operate before this temperature is reached)
- designed to absorb localised heat by specific K factor spray patterns. It is anticipated that this may be best achieved with the use of higher flow rate deflectors that discharge fine droplets. However, mist systems should be avoided as there is a risk that if used the sprinkler system could become ineffective once the boost ventilation is activated
- installed so that the sprinkler heads are no more than 500mm above the highest vehicle using the charging bay.
- town mains supplied. For new builds consideration should also be given to installing 60-minute water supply tanks to supplement towns mains should the mains supply pressure fail.

For lorry and large vehicle charging areas reference should also be made to fire suppression systems designs, for roll on roll off marine ferries.

<u>Fire detection</u>

Fire detection to be installed in addition to fixed Automatic Fire Suppression Systems (AFSS) sprinklers. Detection to be multi - sensor type (i.e. optical or heat).

The car park/basement fire alarm system should be a P2 standard in accordance with BS 5839. However, it is recommended that this specification is upgraded to a P2 –L5 system standard in the actual charging area to be assist early detection of a fire and that where possible the detection system within this area is linked with sprinkler actuation.

To further assist early detection, it is desirable is to link security CCTV to an addressable fire alarm. This will allow those monitoring security cameras to see an incident in the battery charging area as soon as the "smoke" is detected by the alarm syste ı and potentially respond more rapidly to the evolving situation.

Where automatic vehicle access is provided on site. It should be integrated with the fire alarm system to prevent vehicles entering the fire zone except for emergency responders. However, such arrangement should also not prevent vehicles leaving, unless this is assessed to be a security risk.

The system design should ensure that manual call points are located close to charging areas.

<u>Suggested detection positioning</u>

Detector Type BS 5839 Part 1 is relevant but does not cover fire alarm operating and other systems therefore please also see – BS 7273-6:2019.	**Coverage**	**Location**
Smoke	7.5m centres Radius 5.3m	15m centres Radius 10.2m
Heat	5.3m centres Radius 3.8m	10.6m centres Radius 7.6m

8.8 Standards to protect people's health and the environment

It is anticipated that electric vehicles, chargers and associated cables will emit electromagnetic forces (EMF) when energised. At present there is no UK legislation specific occupational exposure limits for EMF. Control is exercised through the general duties in the Health and Safety at Work etc. Act 1974, the Management of Health and Safety at Work Regulations 1999 and by reference to ICNIRP guidelines.

A study in 2014-2015 followed hundred and eight patients with cardiac implantable electronic devices exposed to EMF radiation by the four most common electric cars (Nissan Leaf, Tesla Model S, BMWi3, VW eUp) while roller-bench test driving at Institute of Automotive Technology, Department of Mechanical Engineering, Technical University, Munich. The study showed that EMF radiation did not affect CIED function in a cohort group[17].

Whilst writing this guidance similar studies have not been found on charging units. It is, therefore, recommended that an EMF survey is undertaken of the installation or confirmation obtained from the manufacturers to ensure that those with cardiac implantable electronic devices and others who could potentially use or work near the chargers will not be placed at increased risk.

Charging units are to be protected from vehicle impact and other such mechanical damage. This may be achieved by the provision of barriers or kerbing, etc.

A fire involving a lithium ion battery will generate several toxic chemicals that will contaminate surrounding surfaces. Fire fighters have advised that based upon manufactures information 2 hours of water maybe need to control such a fire. For these reasons:

- surfaces such as the floor walls and ceiling of the charging area should not be porous and facilitate the environmental clean-up of toxic chemicalcontamination
- drainage should incorporate "petrol" interceptors and the general design should resist pollution and contaminated water entering natural water supplies such as rivers or bore holes

8.9 Standards to support business continuity following a lithium ion battery fire

Following a lithium-ion battery fire an assessment to be undertaken of the toxicity of the contaminated surfaces and equipment so that appropriate steps can be taken to clean the area.

Due to the risk of reignition of damaged battery arrangements may need to be in place for specialist recovery to be undertaken. This may require the battery/vehicle being placed in a container for safe transportation and therefore, designers should consider space requirements for such recovery when designing new installations.

8.10 Signage Standards

The following signs complying with Health and Safety (Safety Signs and Signals Regulations) 1996 are to be erected near the charging area; ideally, they should be both in writing and pictorial form:

- no flammable or combustible materials to be stored
- no washing of vehicles is permitted

In addition, but still complying with the regulations where applicable:

- signs are to be applied to sprinkler system stating that the “system not to be isolated if electric vehicle involved until vehicles are removed from site”
- floor location level signs to be applied on all protected routes
- dry rising mains feeding areas are to be clearly marked with use on both Inlets and outlets
- all emergency isolation equipment and switches are to be clearly indicated and marked showing direction of isolation which is readable in low light
- mechanical protection of barriers protecting charging equipment are to be highlighted

9 Contract project management

9.1 Project managers for electric vehicle charging areas are to ensure that:

- the safety file contains details of the potential fire risks associated with the installation and the maintenance requirements. The file should also contain as built plans of the installations highlighting all emergency isolation points for equipment
- all details of products used and commissioning certificates are obtained prior to building use and passed to the Premises Controller (Where a building is erected or extended, or has undergone a material change of use, and the Regulatory Reform (Fire Safety) Order 2005 applies to that building or extension, Regulation 38 requires that a package of fire safety information – ‘as built’ information which records the fire safety design of the building or extension – must be assembled and given to the 'responsible person' for the premises by the contractor)

10 Premises Controllers

10.1 Premises Controllers are to ensure that the building/structures fire risk assessment reflects the installation of fast, rapid or super vehicle battery chargers on site and update their sites fire safety management arrangements. This will include providing instruction to relevant staff on what to do on discovering electric vehicle or charging unit fire.

10.2 Under proposed legislation Premises Controllers are likely to have to hold or have ready access to a digital building file, containing a section on fire and details of the fire loading risks imposed from onsite battery charging.

10.3 Premises Controllers must also ensure that systems are in place to maintain battery charging units in accordance with manufactures instructions and ideally SFG 20 specification. They should also ensure maintenance remains up to date and that records are kept available for inspection by the fire brigade, Health and Safety Executive inspectors, City health, safety and fire practitioners, etc.

10.4 Premises Controllers are advised to produce a risk assessment for the general use of electric vehicle chargers at their sites

Diagram: 1 CoL recommended car park spacing

Vehicle to drive into bay stopping short of hatched areas, allowing access for charging.

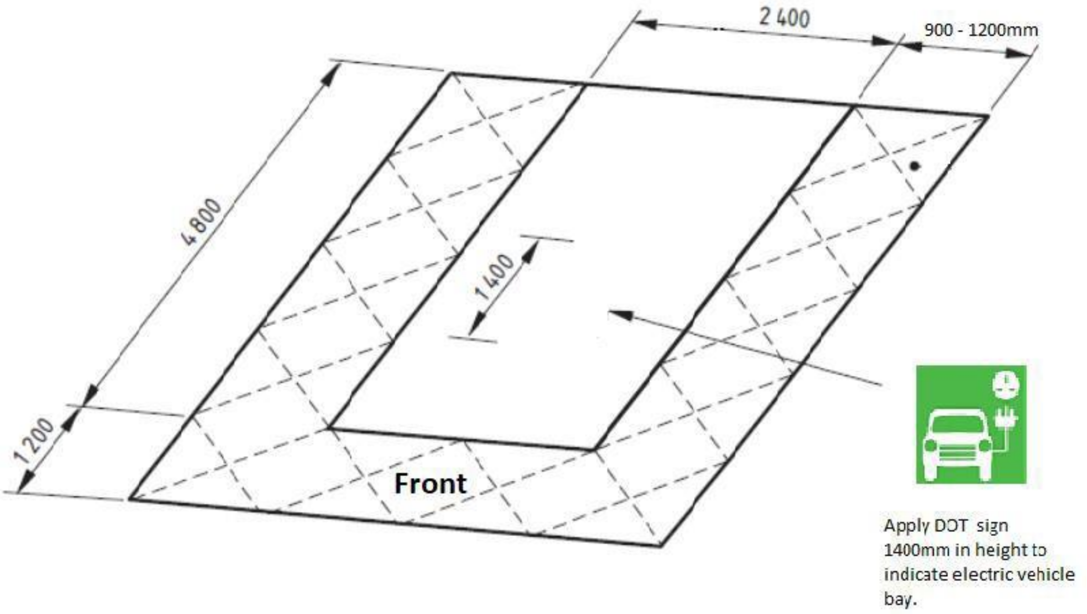

Photo: 1 Relaxation of compartmentation design by supplying bays in permanent compartmentation area

Photo: 2 Example of stall board external ventilation under shop fronts

Types of charging[37]

The length of time EV batteries take to recharge is determined by how many kilowatts (kW) the charging station can provide and how many the car can accept – the higher the wattage, the faster the charge. The following different rates exist.

Slow Charging Rate: 3KW
Slow charging is most suited to the home or office, where vehicles can be charged throughout the day or overnight. Alternatively, the battery can be topped up while shopping, or visiting an area. Charging a car from flat or 'empty' (either at home or at a charging station), on a full slow charge will typically take around eight hours.

Fast Charging Rate: 7-22KW
A fast charging point will take around three to four hours to fully charge the batteries from flat. Most public charging stations offer this rate

Rapid Charging Rate: 43-50KW
Only a few EVs are compatible with rapid charging, which will allow an 80% charge from flat, in as little as 30 minutes. Public charging points that offer rapid charging aren't as common as fast chargers, but Tesla has its own proprietary network for use exclusively with its cars.

Super Charging Rate: 150KW
"Petrol suppliers have" announced "that" they are launching 'super chargers', which will provide an 80% charge in ten minutes, at selected filling stations.

Electric vehicle charging can happen at different speeds depending on the type of vehicle, usage pattern of the location and type of charge point. The table below sets out the key charging types, where they normally are found and an indicative charging time[9].

Charge point Power	Current	Connector	Mode	Typical Location	Example charging time
3.6 kW	AC	Type 1/ Type 2	Mode 3	Homes, on-street locations, destinations	c. 11 hours
7kW	AC	Type 1/ Type 2	Mode 3	Homes, on-street locations, destinations	c. 5 - 7 hours
22kW	AC	Type 1/ Type 2	Mode 3	Destinations	c. 2 hours
50kW	DC	CCS/ CHAdeMO	Mode 4	Motorway Service Areas / destinations	<1 hour
150kW+	DC	CCS/ CHAdeMO	Mode 4	Motorway Service Areas / destinations	<30 minutes

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