INSPECTION REPORT

Fire Safety Assessment according to EN 45545-2, EN 45545-5 and NFPA 130

Power supply unit (PSU) VCCR300

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Customer:

Vox Power Ltd

Unit 2, Redcow Interchange Estate, Ballymount

D22 Y8H2, Dublin

Ireland

Order Date: 2023-02-02

Project No.: 717527102

Inspector:

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Revision history

Version	Status	Date	Author	Modified clauses	Modifications
0.1	Draft	2023-05-15	Kangyi Xu	---	---
1.0	Released	2023-05-17	Kangyi Xu	All	Initial

1. Client

Vox Power Ltd

Unit 2, Redcow Interchange Estate, Ballymount

D22 Y8H2 Dublin

Ireland

2. General

2.1. Contract

The fire safety assessment for the Vox Power Power supply unit (PSU) VCCR300 was commissioned by the company Vox Power to TÜV SÜD Rail GmbH on 2023-02-02.

The assessment was carried out in the period from 2023-02-02 to 2023-05-17 by inspection of the documents provided by the client Vox Power or its subcontractors.

The expert involved is an employee of TÜV SÜD Rail GmbH and is not instructed by the preparation of the inspection report.

2.2. Standards

This document deals with the assessment of the Vox Power Power supply unit (PSU) VCCR300 in respect to compliance with the fire safety requirements according to the following acknowledged rules of technology:

Table 1: Standards

No.	Standard	Title
[R01]	DIN EN 45545-1: 2013-08*	Railway applications – Fire protection on rail vehicles – Part 1: General
[R02]	DIN EN 45545-2: 2016-02*	Railway applications – Fire protection on rail vehicles – Part 2: Requirements for fire behaviour of material and components
[R03]	DIN EN 45545-2: 2020-10	Railway applications – Fire protection on rail vehicles – Part 2: Requirements for fire behaviour of material and components
[R04]	DIN EN 45545-5: 2016-01*	Railway applications – Fire protection on rail vehicles – Part 5: Fire safety requirements for electrical equipment including that of trolley buses, track guided buses and magnetic levitation vehicles
[R05]	NFPA 130:2023	Standard for Fixed Guideway Transit and Passenger Rail Systems

* This standard is part of the accreditation D-IS-11190-01-00

2.3. Abbreviations

Table 2: Abbreviations

Abbreviation	Definition
HL	Hazard Level
max.	Maximum
min.	Minimum
N/A	Not Applicable
OC	Operation category
OI	Oxygen Index
PCB	Printed circuit board

2.4. Management system at the time of inspection

The inspection was executed under application of the valid quality management system [M1] of the inspection body TÜV SÜD Rail GmbH accredited according to DIN EN ISO/IEC 17020:2012 [M2].

Table 3: Management System

Ref.	Designation	Title
[M1]	QMS	Quality management system of TÜV SÜD Rail GmbH
[M2]	D-IS-11190-01-00	Accreditation by the DAkkS according to DIN EN ISO/IEC 17020:2012 as a Type A inspection body. The accreditation is only valid for the scope of accreditation listed in the document annex D-IS-11190-01-00.

3. Documents

Table 4: Documents

ID	Title	Author	Doc./File ID	Date	Rev.
[D1]	Material list VCCR300	Vox Power	FCIL_VCCR300_R01	---	1
[D2]	Data sheet VCCR300	Vox Power	DOC-DTS-034-02	---	---
[D3]	User manual VCCR300	Vox Power	DOC-MN-009-01	---	---
[D4]	Test report PCB	UL	E109769	2023-01-01	---
[D5]	UL Certificate Gap pad TG-A	UL	E314841	2023-01-01	---
[D6]	UL Certificate A3 RV0 / A 63 R V0	UL	E86034	2023-01-01	---

4. Equipment under inspection

4.1. Description of equipment

The Power supply unit (PSU) VCCR300 was developed for application in rolling stock.

The VCCR300 series of conduction-cooled power supplies are designed to provide a DC/DC power source that can provide 300 watts of power in a 188.6 (L) x 116 (W) x 25.4 (H) mm housing. The input voltage has a wide range of 33.6 V to 160 V. Output voltages of 12 V, 24 V, 36 V and 48 V are available with a wide adjustment range from 90% to 125%.

The chassis is made of aluminum and the cover from steel. There are 3 types of interfaces on the device, the J1 for DC input voltage, the J2 for user controls and the J3 for DC output voltage.

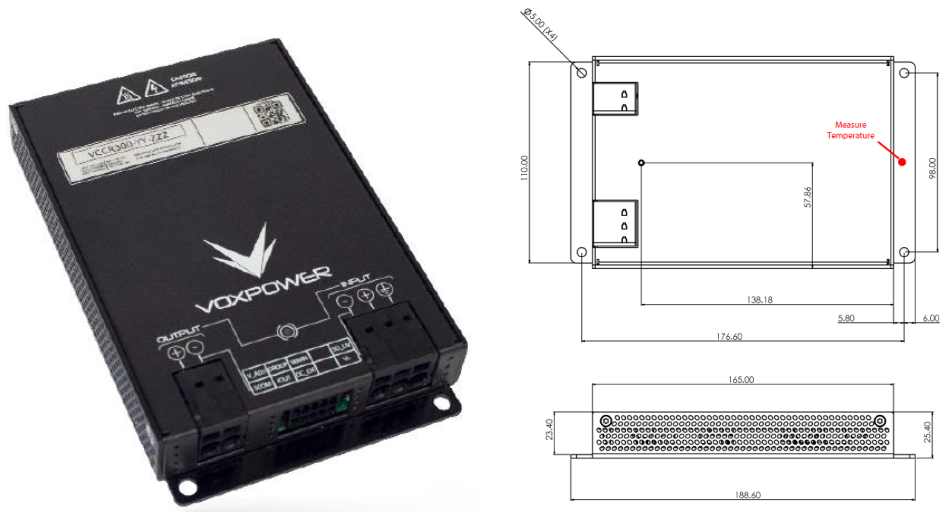

Fig. 1 Power supply unit (PSU) VCCR300 – source: Vox Power

Connection cables of the vehicle wiring or brackets for mounting are not part of this assessment.

4.2. Electrical Data

Table 5: Power supply unit (PSU) VCCR300 - Electrical data

No	Part name	Voltage	Fuse	Max. power
1	VCCR300	Input: 33.6 V to 160 V Output: 12 V, 24 V, 36 V, 48 V	15 A	Input: 400 W Output: 300 W

4.3. Installation Conditions

The Power supply unit (PSU) VCCR300 is intended for installation in interior technical compartment. It is not regularly accessible for passengers or staff during operation.

5. Conformity assessment acc. to EN 45545

5.1. Classification according to EN 45545-1

The Power supply unit (PSU) VCCR300 is to be used in vehicles of all design categories and for operation in all environments corresponding to operation categories 1 to 4.

The safety objectives according to EN 45545-1, Section 4.2 “Fire resulting from accidental ignition or arson”, Section 4.3 “Fires caused by technical defects” as well as Section 4.4 “Fire resulting from larger ignition models than those described in 4.2 and 4.3” have been incorporated in the assessment in a risk-oriented approach.

Section 4.2 refers to typical ignition models involving newspaper, matches, cigarettes and gas lighters. Those will be taken into consideration for any areas that are freely accessible to passengers and staff (ignition models 1 and 2 in accordance with Annex A, EN 45545-1). According to the intended installation conditions in 4.3 of this report, the access for passengers is regularly not intended. Hence this ignition model has not been considered in the following assessment.

Section 4.3 refers to ignition models comparable to electrical arcing or overheating and the spread of fire by any potentially flammable gases and liquids present (ignition models 3 and 4 in accordance with Annex A, EN 45545-1).

Section 4.4 refers to larger ignition models (model 5 in accordance with Annex A, EN 45545-1) than those defined in sections 4.2 and 4.3 of EN 45545-1. The assessment of this ignition model was made with focus on the material selection and the intended installation conditions.

According to section 8, the proof of conformity must be provided for the defined fire protection requirements. Proof of conformity for the fire behaviour of materials and/or components can be provided in the form of test reports or certificates.

- Test reports must be issued by testing laboratories that are accredited for the respective tests according to EN ISO/IEC 17025.
- Certificates must be issued by certification bodies, which are accredited for the respective testing or classification standards according to EN ISO/IEC 17065.

5.2. Assessment according to EN 45545-2

5.2.1. Requirements

Based on the classification according to EN 45545-1, the materials / components shall meet the requirements of Hazard Level 3 (HL3). The components are to be regarded as Electrotechnical equipment covered by the EN 45545-2 standard. Generally, the requirement sets are listed in section 4.4 “Listed products”. The applicable requirements are the following:

Table 6: Requirement sets

No.	Name	Details	Requirement
EL9	Printed circuit boards	Printed circuit boards with all applied coatings but without any attached technical equipment	R26 [R03] EN 60695-11-10 Classification = V0 or R25 EN 60695-2-11 Glow Wire 850 °C or R24 ISO 4589-2 OI ≥ 32 %
EL10	Small electrotechnical products	All electrotechnical equipment, including protection against contact and similar	R26 EN 60695-11-10 Classification = V0

In addition to the requirements of listed products, the grouping rules according to section 4.3 for components with low combustible mass and / or surfaces are applicable.

No requirements apply to products with a combustible mass of < 10 g not in touching contact with another unclassified product (EN 45545-2 section 4.3.1).

Table 7: Grouping rule 1

No.	Section	Requirement	Remark
1-1	4.3.2. Grouping rule 1 Products without requirements	< 100 g for interior grouped products	No requirements
1-2		< 400 g for exterior grouped products	No requirements

Table 8: Grouping rule 2

No.	Section	Requirement	Remark
2-1	4.3.3. Grouping rule 2 Products tested according to R24	< 500 g for interior grouped products tested according to R24	Proof R24 Oxygen index
2-2		< 2000 g for exterior grouped products tested according to R24	Proof R24 Oxygen index

The following general rules shall be considered:

Table 9: General requirements

Section	Requirement	Remark
4.2. a) General	Products which comply with the highest level of reaction to fire performance and therefore need no further testing are - products classified as A1 according to EN 13501-1 - all products described in commission decision 96/603/EC (as amended)	---

Table 9: General requirements

Section	Requirement	Remark
4.2 m) [R02] 4.2. l) [R03] Size of test specimen	If the end use condition does not allow sizes of test specimen for ISO 5658-2 (if this is part of the requirement set): R6 interior use R9 exterior use	---
4.2. n) [R02] 4.2. m) [R03]	If listed products are used in an application below the mass and area thresholds given in 4.3, they may be treated as non-listed products.	---
4.5 non-listed products	Any product not listed in EN 45545-2 Table 2 shall be considered as a non-listed product or shall be assessed using the grouping rules stipulated in EN 45545-2 section 4.3. The requirements of non-listed products are the following: > 0.2 m² R1 (interior), R7 (exterior) ≤ 0.2 m² R22 (interior), R23 (exterior)	This requirement can also be applied to any product that cannot be tested according to the requirements of listed products, if the exposed area is < 0.2 m².
4.7 Products to be approved on functional necessity	If it can be shown that any of the requirements specified above are not technically achievable with functionally suitable products, then existing commercially available products can be used until and unless a suitable product is developed. There shall be no requirement to consider products made available after the date after the date of the contract.	---
5.3.6 [R02] 5.3.7 [R03] Fire integrity test	There shall not be more than one hole after the test T03.01. or T03.02. This hole shall have no dimension in the plane of the test piece greater than 3 mm. Alternatively, the material fulfils the requirements of Conventional Classified Products acc. to EN 45545-3. Those products are considered to meet the integrity requirements.	Materials that are fully separated with those products shall be grouped separately.

5.2.2. Material verification

The combustible materials are listed in the material list [D1].

According to the available documentation the combustible material required to be verified by test are PCBs and small electrotechnical products. The relevant requirements according to EN 45545-2 as well as the test results are listed in Table 10. All other combustible materials can be grouped or have a combustible mass of less than 10 g with no touching contact with any other unclassified material and are therefore not required for verification by test.

Table 10: Listing of material testing

Material	Requirement	Result	Certificate	HL
EL9 - PCB S1000H / S1000-2M	*R25 / R24 (R26)*	 fulfilled R26	 [D4]	 HL3
EL10 - Small electrotechnical product PCB Gap pad TG-A Wago plugs A3 RV0 / A 63 R V0	*R26*	 fulfilled fulfilled	 [D5] [D6]	 HL3 HL3

Material treated according to the grouping rules > 10 g but < 100 g:

- Grouping with a total combustible mass of 78 g, consisting of small electronic parts, e. g. resistors, diodes, capacitors on PCB

The grouped combustible mass does not need to be considered when integrated into the vehicle, as the material of the metallic housing fulfils the fire integrity requirements acc. to section 5.3.6 of EN 45545-2:2016 / 5.3.7 of EN 45545-2:2020.

The combustible materials used for the Power supply unit (PSU) VCCR300 fulfil the requirements according to EN 45545-2 for HL3.

5.3. Requirements for EN 45545-5

EN 45545 part 5 focuses on safety requirements for electrical equipment in railway vehicles with the goal of reducing to a minimum the risk of a fire and of a technical error and/or failure of equipment which may occur as a result. The requirements are listed in the following tables and compliance with the design is assessed.

5.3.1. Assessment for EN 45545-5, chapter 4

Table 11 - General requirements: Requirements of EN 45545-5, chapter 4

No.	Section	Requirement	Evaluation
4	General requirements	Environmental requirements EN 50125-1 – prove acc. to EN 50155	-40°C to +70°C, +85°C 10 mins [D2]
		Wiring and the reliability of the connections in accordance with EN 50343 Air clearance and creepage acc. to EN 50124	N/A, the connections to the vehicle are the responsibility of the vehicle manufacturer.
		Requirements for fire behaviour according to EN 45545-2	See chapter 5.2

5.3.2. Assessment for EN 45545-5, chapter 5

Table 12 - Design requirements: Requirements of EN 45545-5, chapter 5

No.	Section	Requirement	Evaluation
5.1	Overload protection	Selection and design of overload protection between current collector and consumer	N/A
		Selection of other overload protection devices (fuses, circuit breakers)	Positive line fused with 15 A [D2]
		Unprotected circuits	Not present
5.2	Wiring	Cable cross section, environmental requirements	N/A
5.4	Housing	Screen to prevent touching Fire protection enclosure Danger of explosion	IP30, Chassis base material: Aluminium, Chassis cover material: Steel [D2]
5.5	Cable channels	Temperature rise, water drain	N/A

Table 12 - Design requirements: Requirements of EN 45545-5, chapter 5

No.	Section	Requirement	Evaluation
5.6	Batteries and battery power circuits	Ventilation, short circuit protection	N/A
5.7	Switchgear equipment	Spark arresting, overload current	N/A
5.8	Electrical emergency equipment	Cable installation in the vehicle	N/A
5.9	Protective connections	Protection against electrical hazards	Pin 3 on J1 - DC input voltage is for protective earth [D2]
5.10	Resistors and heating elements	Surface temperatures	N/A
5.11	Installation locations in the current collector area	Spark arresting	N/A
5.12	Forced ventilated equipment	Switching off the forced ventilation	N/A
5.13	Container with liquid insulating material	Combustible fluids	N/A

6. Conformity assessment acc. to NFPA 130

6.1. Scope and goals of NFPA130

The standard covers "[...]fire protection requirements for fixed guideway transit and passenger rail systems, including, but not limited to, stations, trainways, emergency ventilation systems, vehicles, emergency procedures, communications, and control systems" (see NFPA 130, section 1.1.1).

According to the section 4.2.1 of the NFPA 130 "*The goals of this standard shall be to provide an environment for occupants of fixed guideway and passenger rail system elements that is safe from fire and similar emergencies to a practical extent based on the following measures:*

(1) Protection of occupants not intimate with the initial fire development

(2) *Maximizing the survivability of occupants intimate with initial fire development*"

6.2. Assessment according to NFPA 130

6.2.1. Requirements

The requirements of the NFPA 130 section 8 are taken as a basis for the assessment. Only the requirements applicable to the Power supply unit (PSU) VCCR300 mounted in a railway vehicle are evaluated. The cables and any additional bracket are not part of this assessment.

The key requirement characteristics from section 8 of NFPA 130 are as follows:

Table 13: Requirement characteristics of NFPA 130 section 8

Section	Content	Requirement characteristics / Keywords
8.	**Vehicle**	
8.1	Applicability	New and retrofitted vehicles
8.1.1	New Vehicles	New Vehicles: "All new passenger carrying vehicles shall be, at a minimum, designed and constructed to conform to the requirements set forth in this section."
8.1.2	Retrofitting	Retrofit: "Where existing passenger-carrying vehicles are to be retrofitted, the appropriate sections of this standard shall apply only to the extent of such retrofit."
8.2	Compliance Options	Alternative: Fulfilment of prescriptive requirements in section 8.3 - 8.10 for passenger vehicles *or* application of engineering analysis (8.11)
8.4	Flammability and Smoke Emission	sub-divided in 8.4.1 (fire test procedures and performance criteria for materials) and 8.4.2 (fire hazard analysis for material not fulfilling the req. of section 8.4.1)
8.4.1	Requirements and test methods	The test procedures and minimum performance for materials and assemblies shall be as detailed in Table 8.4.1 Material requirements, component assembly, test methods; reference to numerous ASTM codes

Table 13: Requirement characteristics of NFPA 130 section 8

Section	Content	Requirement characteristics / Keywords
8.4.2	Material handling, that do not comply with 8.4.1	In case of deviation refers to a risk-based approach
8.6	Electrical Fire Safety	physical, mechanical, and electrical performance of cables: ICEA S-95-658/NEMA WC-70 or ICEA S-73-532/NEMA WC-57, as applicable wire size: 2.1 mm^2 or 0.33 mm^2 respectively Air clearance, creepage from Annex F
8.11	Engineering Analysis Option	Option for analysis (refer to 8.2) if prescriptive requirements are not applicable; general (qualitative) requirements; need for independent review or approval

The materials and assemblies must meet the fire test procedures and performance criteria listed in NFPA 130 table 8.4.1.

In accordance with NFPA 130 section 8.4.1.10 and annex A.8.4.1.10, materials used to fabricate miscellaneous, discontinuous small parts where the surface area of any individual small part is less than 100 cm^2 in end use configuration and that will not contribute materially to fire growth in end use configuration can be evaluated by an appropriate fire hazard analysis (N 8.4.1.10.1) or can be tested in accordance with ASTM E1354 (N 8.4.1.10.2).

In accordance with NFPA 130 section 8.4.2, materials not complying with the requirements of NFPA 130 Table 8.4.1 shall be permitted in limited areas of the vehicle, if it is demonstrated by an appropriate fire hazard analysis with an equal or less fire hazard than compliant materials in the same location with similar function.

6.3. Material verification for NFPA 130

The combustible materials are listed in the material list [D1]. Based on available documentation, no combustible material has been verified by testing in accordance with NFPA 130 Table 8.4.1.

According to the intended installation conditions in 4.3 of this report, the Power supply unit (PSU) VCCR300 are intended for use in interior technical compartment only. The area for using this device is limited and the access for passengers is regularly not intended.

The total combustible mass of these parts is about 226 g and is therefore very limited [D1].

The combustible materials used for the Power supply unit (PSU) VCCR300 shall be assessed by fire risk analysis.

6.4. Fire risk analysis

The Power supply unit (PSU) VCCR300 consists of different small components built together [D1]. Each component is listed on material list. The combustible mass of

discontinuous small parts relevant to the fire risk analysis is about 226 g.

6.4.1. Fire Risk Analysis Method

For the fire risk analysis, the standards DIN EN 60812 and DIN EN 50126 are taken as guidelines.

Three parameters are taken in consideration:

- **Severity**, this parameter classifies how big the impact of a failure will be
- **Occurrence**, this parameter classifies how often a failure can happen
- **Detection**, this parameter classifies how easy or difficult is to detect a failure

These parameters are calculated using the following tables:

Table 14: Severity (S)

Value	Frequency	Meaning	Personal Safety
1	Category 4 (Insignificant)	A fire of the component results in a negligible severity: No fire or limited, enclosed fire inside a rack, cabinet or container box	no or little risk to persons
3	Category 3 (Marginal)	A fire of the component results in a medium severity: Enlarged fire consequence – spread to surrounding location (e.g. to passenger compartment, to underfloor area)	Hazard to persons (Slightly injured and / or significant environmental damage)
5	Category 2 (Critical)	A fire of the component results in a high severity: Fully developed fire possible	acute danger to persons (individual accident victim and / or severely injured and / or significant threat to Environment)

Table 15: Occurrence (O)

Value	Frequency	Meaning
1	Level E - Improbable	The hazard can be expected to occur exceptionally seldom during system life cycle.
3	Level D – Remote	The hazard can be expected to occur sometime during system life cycle.
5	Level B – Probable	The hazard can be expected to occur several times during system life cycle.

Table 16: Detection (D)

Value	DIN EN 60812 Likelihood of detection	Meaning
1	Frequent	Fire/ failure detection or reported fire followed by persistent and self-sustaining shut off
2	Occasional	Fire/ failure detection or reported fire not followed by persistent and self-sustaining shut off
3	Rare/Remote	Open visible fire
5	Improbable	The component is not directly visible, the fire detection is practically impossible (hidden fire)

After the single valuation of each parameter, a calculation is done to consider if the risk

is acceptable through the RPN. The RPN is calculated with the following formula:

RPN = (Severity) x (Occurrence) x (Detection)

The evaluation of the RPN and thus the fire risk is based on the risk categories according to EN 50126, as described in the following Table 17.

Table 17: Fire risk assessment based on the RPN

RPN	Risk category	Measures to be applied
1 ≤ RPN ≤ 15	Negligible	Risk can be accepted without measures
15 < RPN ≤ 30	Tolerable	Risk can be accepted with appropriate monitoring
30 < RPN ≤ 50	Undesirable	Risk may only be accepted if risk reduction is not practically feasible
50 < RPN ≤ 125	Intolerable	Risk must be excluded

The calculation of RPN and the result are shown in the following Table 18:

Table 18: Calculation of RPN

Parameter	Value	Justification	RPN Result (S x O x D)
Severity (S)	1 (Cat. 1)	Due to the small combustible mass, the severity of a fire is insignificant or marginal. A spread of the fire to other components cannot be completely excluded. Therefore, a conservative evaluation results in a value of S = 1.	**5**
Occurrence (O)	1 (Lev. E)	A fire due to technical failure of the device is very unlikely because the max. power is limited to 400 W. The evaluation results in a value of O = 1	
Detection (D)	5	The device is mounted inside the railway vehicle in a technical compartment. They are not directly visible for passengers or staff during operation. The evaluation results in a value of D = 5	

Based on the RPN of 5 the Fire Risk according to the Table 17 is negligible. No additional measures need to be taken. The installation of the Power supply unit (PSU) VCCR300 in the technical areas does not involve any additional risks.

7. Plausibility check of the ignition sources

7.1. Fire development starting from the component

The maximum power is limited by internal fuse (15 A, positive line fused (5x20 Fast acting, 1500A breaking capacity)). The theoretical ignition potential in the event of a failure, irrespective of the technical cause, is below the relevant ignition model 4 (max. 1 kW over 30 seconds) in accordance with Annex A, EN 45545-1. Due to the small amount of combustible mass, the predominantly qualified materials and the low electrical power, which is limited in time by the existing fuse, ignition and fire development in the event of an electrical failure are sufficiently prevented from "fire caused by technical defects", in accordance with EN 45545-1, Chapter 4.3. In addition, the metal housing protects against further fire spread in the unlikely event of ignition.

7.2. Fire involvement of the component by external ignition source

An external fire event, starting from a vandalism or technique fire, can affect the materials with thermal radiation (ignition models 2 and 3 according to Annex A, EN 45545-1) and additionally with direct flame or arc action (see ignition models 1 and 4 according to Annex A, EN 45545-1) and involve them in the fire. The materials have been qualified in terms of ignition prevention at low ignition power, which does not completely prevent fire involvement in major fire events. The component housing is made of non-combustible material and the combustible mass of the component is very low, which greatly limits the promotion of fire spread.

8. Summary

As result of this assessment, the Power supply unit (PSU) VCCR300 meets the requirements of the listed acknowledged codes of practice:

- EN 45545-2:2020 hazard levels HL1 to HL3
- EN 45545-5:2016
- NFPA 130:2023

Groupings to be considered for installation in the vehicles (see section 5.2.2):

- none

For regular intended operation the required level of safety for passengers and staff is ensured.

This inspection report was written under the specified accreditation without influence of third party.

TÜV SÜD Rail GmbH, Unit Rolling Stock

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