PELTON TURBINE DESIGN PDF

Pelton Turbine Design: An In-Depth Overview

Pelton turbine design plays a pivotal role in harnessing hydroelectric power from high-head water sources. As a type of impulse turbine, the Pelton turbine is renowned for its efficiency, simplicity, and robustness, making it a preferred choice for high-head hydroelectric projects worldwide. Understanding its design intricacies is essential for engineers, hydropower developers, and students aiming to optimize performance and longevity of these turbines. This comprehensive guide explores the fundamental components, design considerations, and advanced features of Pelton turbines to provide a clear understanding of their engineering principles.

Introduction to Pelton Turbine

What is a Pelton Turbine?

The Pelton turbine is an impulse hydraulic turbine designed primarily for high-head, low-flow water resources. It converts the kinetic energy of water jets into mechanical energy by directing water onto a set of spoon-shaped buckets mounted on a wheel (runner). The high-velocity water jet strikes the buckets, causing the runner to rotate, which is then used to generate electricity via a connected generator.

Historical Background

Developed by Lester Allan Pelton in the 1880s, the Pelton turbine revolutionized hydroelectric power generation with its efficient impulse design. Over the years, its engineering has been refined to optimize performance across various applications.

Fundamental Components of Pelton Turbine Design

- Runner (Impulse Wheel)

The core component responsible for converting water jet impact into rotational mechanical energy. It consists of:

- Buckets: Spoon-shaped blades that capture water jet energy.
- Hub: Central part attaching buckets to the shaft.

- Nozzle Assembly

Directs water from the penstock into a high-velocity jet. Key features include:

- Nozzles: Usually adjustable to control flow rate.
- Gates or Valves: Regulate water flow for operational control.

- Penstock

A pipe that supplies high-pressure water from the reservoir to the nozzles.

- Draft Tube (Optional)

In some designs, a draft tube guides water away from the turbine runner after energy extraction, improving efficiency.

- Shaft and Bearings

Support the runner and transfer mechanical energy to the generator.

Key Design Considerations in Pelton Turbine

Designing an efficient Pelton turbine involves multiple engineering factors:

- Head and Flow Rate

- High Head: Typically above 300 meters, suitable for Pelton turbines.
- Flow Rate: Must be optimized to match the turbine's capacity and efficiency.

- Nozzle Design

- Number of Nozzles: Usually 1-4; multiple nozzles increase power but add complexity.
- Nozzle Diameter: Determines jet velocity; larger diameters produce higher flow but lower

velocity.
- Flow Control: Adjustable nozzles allow for efficient operation under varying water flow conditions.

- Bucket Shape and Size

- Design: Spoon-shaped with a particular curvature to efficiently capture and transfer water energy.
- Material: Durable, corrosion-resistant materials to withstand water impact and environmental conditions.

- Runner Geometry

- Number of Buckets: Typically 20-40 per runner, depending on size.
- Bucket Arrangement: Evenly spaced to balance forces and minimize vibrations.
- Blade Curvature: Designed to optimize impact angle and energy transfer.

- Velocity and Power Calculations

- Jet Velocity (V): Calculated based on water head (H) using Bernoulli's equation:

V = ?(2gH)

where g = acceleration due to gravity.

- Power Output: Derived from flow rate and jet velocity, considering efficiency factors.

Advanced Design Features and Innovations

- Adjustable Nozzles and Pitching

Allow operators to control jet velocity and angle for optimal efficiency across varying flow conditions.

- Multiple Nozzle Systems

Increase power output and operational flexibility, especially in large-scale hydropower plants.

- Buckets with Improved Hydrodynamics

Innovations include:

- Streamlined shapes to reduce turbulence.
- Self-cleaning features to prevent debris accumulation.

- Material Enhancements

Use of composite materials or specialized alloys to:

- Reduce weight.
- Increase wear resistance.
- Extend lifespan.

- Dynamic Balancing and Vibration Control

Implementation of sensors and control systems to monitor operational stability and reduce maintenance needs.

Design Calculations for Pelton Turbine

- Power Output Estimation

$$ P = \eta \times \rho \times g \times Q \times H $$

Where:

- P = Power (Watts)
- η = Overall efficiency

- ρ = Water density (~1000 kg/m³)
- g = Gravitational acceleration (~9.81 m/s²)
- Q = Flow rate (m³/s)
- H = Water head (meters)

- Nozzle Velocity

$$V = \sqrt{2gH}$$

This velocity influences bucket design and runner size.

- Bucket Impact Angle

Optimal impact angle (usually close to 180°) ensures maximum energy transfer and efficiency.

Maintenance and Optimization

- Regular Inspection

- Check for erosion or corrosion of buckets.
- Ensure nozzles are free from debris and wear.

- Lubrication

Proper lubrication of bearings and rotating parts reduces wear and operational noise.

- Flow Regulation

Adjust nozzles and gates to maintain optimal flow and prevent cavitation.

- Vibration Monitoring

Use sensors to detect imbalances or misalignments early.

Conclusion

The pelton turbine design is a sophisticated blend of fluid mechanics, structural engineering, and materials science, aimed at maximizing efficiency for high-head hydroelectric applications. From the precise shaping of buckets to the adjustable nozzles and runner geometry, each aspect is tailored to optimize energy conversion while ensuring durability and ease of maintenance. With ongoing innovations in materials and control systems, Pelton turbines continue to evolve as a reliable and efficient solution for harnessing renewable energy from water sources. Understanding these design principles enables engineers to develop turbines that are not only high-performing but also sustainable and cost-effective for future hydroelectric projects.

Pelton turbine design is a fascinating and highly efficient technology that has played a crucial role in harnessing hydroelectric power for over a century. As a type of impulse turbine, the Pelton turbine is predominantly used for high-head hydroelectric schemes, converting the kinetic energy of water into mechanical energy with remarkable efficiency. Its design intricacies, operational principles, and ongoing innovations make it a subject of continuous interest for engineers, researchers, and power producers alike.

Introduction to Pelton Turbine Design

The Pelton turbine was developed in the late 19th century by Lester Allan Pelton and has since become a cornerstone in high-head hydroelectric power generation. Unlike reaction turbines, which operate under a pressure head, the Pelton turbine functions as an impulse turbine, utilizing the velocity of water jets to turn the turbine wheel. Its unique design allows it to operate effectively at high heads, typically ranging from 100 meters to over 1000 meters, making it ideal for mountainous regions and large-scale hydro projects.

The core principle of the Pelton turbine revolves around converting the kinetic energy of water?delivered via high-velocity jets?into rotational energy. The water, accelerated through nozzles, strikes the turbine's buckets or blades, causing the turbine wheel to rotate. This rotational energy is then transmitted via a shaft to generators, producing electricity.

Fundamentals of Pelton Turbine Design

Understanding the design of a Pelton turbine requires a grasp of its key components and how they work together:

1. Nozzles

Nozzles are pivotal in transforming the potential energy of water into kinetic energy. They constrict the flow, increasing velocity and directing water jets precisely onto the turbine buckets.

- Design Features:
- Usually, a Penstock directs water to the nozzles.
- Nozzles are adjustable, allowing control over flow rate and jet velocity.
- Multiple nozzles can be used to increase power output and efficiency.

2. Turbine Wheel and Buckets

The turbine wheel, mounted on a horizontal or vertical shaft, hosts the buckets that capture the water jet's energy.

- Bucket Design:
- Typically split into two halves, called split buckets, to optimize flow.
- Shaped to redirect water flow efficiently, minimizing energy loss.
- The shape often resembles a spoon or scoop, designed to absorb the jet's momentum smoothly.

3. Runner (Turbine Wheel)

The runner is the rotating part of the turbine, directly receiving water impact.

- Features:
- Usually made of durable materials like cast iron or bronze.
- Equipped with multiple buckets arranged evenly around the circumference.
- The size and number of buckets influence the turbine?s capacity and efficiency.

4. Draft Tube

Although primarily an impulse turbine, some Pelton turbines incorporate draft tubes to recover kinetic energy as water exits the turbine.

- Purpose:
- Reduces water velocity after it leaves the buckets.
- Improves overall efficiency by minimizing water exit velocity.

Design Considerations for Pelton Turbines

Designing an efficient Pelton turbine involves balancing several parameters:

1. Head and Flow Rate

- High head and moderate to low flow rates are typical for Pelton turbines.
- The design must match the head and flow characteristics of the site to optimize performance.

2. Number and Arrangement of Nozzles

- Multiple nozzles can increase power but complicate balancing.
- Nozzle arrangement impacts jet interference and flow uniformity.

3. Bucket Shape and Size

- Larger buckets can absorb more energy but may increase inertia.
- The bucket shape influences torque and efficiency.

4. Material Selection

- Must withstand high velocities, water hammer effects, and corrosion.
- Common materials include cast iron, bronze, and composite materials.

5. Mechanical Components

- Bearings, shaft design, and seals should be robust to handle operational stresses.
- Maintenance considerations influence design choices.

Operational Features and Efficiency

Pelton turbines are celebrated for their high efficiency, often exceeding 90% under optimal conditions. Their impulse nature means they are less sensitive to variations in head and flow compared to reaction turbines.

Key features:

- Adjustable Nozzles: Allow control over jet velocity and flow rate, facilitating efficient operation across varying water conditions.

- Multiple Nozzles: Enable modular operation, maintenance flexibility, and capacity scaling.
- Balanced Runner: Ensures smooth rotation, reducing vibrations and mechanical wear.

Efficiency Factors:

- Precise nozzle alignment.
- Optimal bucket shape.
- Minimization of water jet turbulence.
- Proper maintenance of bearings and seals.

Design Challenges and Limitations

Despite its advantages, Pelton turbine design involves certain challenges:

- Cavitation: High-velocity jets can cause cavitation, leading to blade erosion.
- Material Wear: Constant impact of water jets causes erosion of buckets over time.
- Nozzle Wear and Blockage: Nozzles are susceptible to clogging and erosion, requiring regular maintenance.
- Limited Applicability: Best suited for high-head, low-flow scenarios; not ideal for low-head sites.

Mitigation Strategies:

- Use of erosion-resistant materials.
- Proper aeration and pressure regulation.
- Regular inspection and maintenance schedules.

Innovations and Modern Developments

Modern Pelton turbine design continues to evolve, focusing on improving efficiency, reducing maintenance, and expanding operational flexibility.

1. Variable Nozzle Control

- Implementing automatic control systems to adjust nozzle flow based on load conditions.
- Enhances efficiency across varying water flow.

2. Improved Materials

- Use of composites and advanced alloys to resist erosion and cavitation.
- Coatings that reduce wear and extend lifespan.

3. Modular Design

- Facilitates maintenance and scalability.
- Allows for easy installation of additional nozzles or replacement of worn components.

4. Computational Fluid Dynamics (CFD) in Design

- Enables precise modeling of water flow, optimizing bucket shape and jet angles.
- Leads to higher efficiencies and reduced energy losses.

Applications of Pelton Turbine Design

Pelton turbines are primarily used in scenarios where high head and low flow are prevalent:

- Mountainous hydroelectric plants.
- Pumped-storage schemes.
- Small-scale hydropower projects where site-specific conditions favor high-head operation.

Their design flexibility allows adaptation to various site conditions, making them versatile tools in hydroelectric power generation.

Conclusion

Pelton turbine design exemplifies the elegant application of fluid mechanics and mechanical engineering principles to harness renewable energy efficiently. Its unique impulse mechanism, combined with innovative design features, makes it ideal for high-head applications where efficiency and reliability are paramount. While challenges such as erosion and maintenance exist, ongoing advancements in materials, control systems, and computational modeling continue to enhance Pelton turbines' performance and longevity. As renewable energy demands grow, the Pelton turbine's role in sustainable power generation is poised to expand, driven by continued innovation and optimized design practices.

In summary, the Pelton turbine remains a critical component in the realm of hydroelectric engineering, embodying a balance of simplicity, efficiency, and adaptability. Its thoughtful design considerations, coupled with modern technological advancements, ensure that it will continue to

generate clean energy for decades to come.

QuestionAnswer What are the key design parameters for a Pelton turbine? The key design parameters include runner diameter, bucket shape and size, jet velocity, number of buckets, and the overall head and flow rate. These factors influence efficiency, power output, and operational stability. How does bucket shape affect the efficiency of a Pelton turbine? The bucket shape determines how effectively the water jet transfers its momentum to the turbine. Optimized bucket designs minimize flow separation and energy loss, thereby increasing efficiency and ensuring smooth water diversion. What materials are commonly used for Pelton turbine buckets, and why? Materials such as stainless steel, bronze, and high-strength alloys are commonly used due to their durability, corrosion resistance, and ability to withstand high velocities and repeated stresses. How does impulse force influence Pelton turbine blade design? Since Pelton turbines operate on impulse force, blade and bucket designs are focused on capturing the water's kinetic energy efficiently. The shape and angle are optimized to direct water flow onto the buckets with minimal energy loss. What are the recent innovations in Pelton turbine design? Recent innovations include computer-aided design (CAD) optimization of bucket shapes, use of advanced materials for longevity, and improved adjustable nozzles for better flow control, all aimed at enhancing efficiency and adaptability. How does the jet angle impact Pelton turbine performance? The jet angle affects how water strikes the buckets; an optimal angle (typically around 165°) maximizes energy transfer and minimizes flow losses, thereby improving overall efficiency. What are the considerations for scaling Pelton turbines for small vs. large hydroelectric projects? Scaling involves balancing factors like flow rate, head height, material strength, and cost. Small turbines prioritize compact design and cost-effectiveness, while large turbines focus on robustness, efficiency, and maintenance for high-capacity operations.

Related keywords: Pelton wheel, impulse turbine, turbine blades, turbine runner, water jet design, turbine efficiency, turbine head, turbine materials, hydraulic flow, turbine cavitation

charlotte and peter fiell

Charlotte and Peter Fiell are renowned figures in the world of design, architecture, and contemporary visual culture. Their collaborative work as authors, researchers, and curators has significantly influenced how we perceive design history and its impact on modern society. With a keen eye for detail and a passion for uncovering the stories behind iconic objects and movements, Charlotte and Peter Fiell have established themselves as authoritative voices in the field. This article delves into their backgrounds, contributions, notable publications, and their lasting influence on design scholarship.

Who Are Charlotte and Peter Fiell?

Background and Career Overview

Charlotte and Peter Fiell are British design historians and authors celebrated for their extensive work on design history and contemporary design trends. Their collaborative efforts have resulted in numerous influential publications that are widely used by students, professionals, and enthusiasts alike.

Charlotte Fiell's academic background is rooted in art and design history, which she has combined with her keen interest in the cultural aspects of design. Peter Fiell, on the other hand, is recognized for his expertise in design criticism and his ability to contextualize design within broader social and cultural frameworks.

Together, they have spent decades researching, writing, and curating exhibitions that highlight the evolution of design from the early modern period to the present day.

Major Contributions to Design Literature

Key Publications

The Fiells are perhaps best known for their comprehensive and visually engaging books that explore various facets of design. Some of their most influential publications include:

- **Design of the 20th Century** ? A definitive guide that chronicles the development of design over the last hundred years, covering everything from industrial design to graphic arts.
- **1000 Lights** ? An extensive survey of lighting design, showcasing innovations and iconic fixtures from around the world.
- **Furniture Design** ? An in-depth look at the evolution of furniture, highlighting key designers and movements that shaped modern interiors.
- **Design Culture: An Anthology** ? A collection of essays and case studies that examine the cultural significance of design across different eras and regions.

Their books are characterized by their rich visual content, combining high-quality photographs, detailed illustrations, and insightful analysis, making them invaluable resources for understanding the history and significance of design.

Curatorial and Exhibition Work

Beyond their publications, Charlotte and Peter Fiell have curated numerous exhibitions that have traveled worldwide. These exhibitions often serve as visual narratives that bring their written work to life, engaging audiences with immersive experiences.

Some notable exhibitions include:

- Modern Masters: Design in the 20th Century ? Showcasing key works from influential designers.
- Lighting the Future ? Exploring innovations in lighting technology and design.
- Furniture of the 21st Century ? Highlighting contemporary trends and emerging designers.

Their curatorial work emphasizes the importance of storytelling in design and underscores the social, cultural, and technological factors that influence creative practices.

Their Approach to Design History

Interdisciplinary Perspective

Charlotte and Peter Fiell advocate for an interdisciplinary approach to understanding design. They believe that design cannot be studied in isolation but must be contextualized within cultural, political, and technological frameworks.

This perspective allows their work to:

- Connect design movements with historical events.
- Analyze the societal impact of technological innovations.
- Explore the ways design reflects cultural identities.

Visual Emphasis

A hallmark of their publications is the emphasis on visual content. They understand that design is a highly visual discipline, and their books are often praised for their stunning imagery that complements scholarly analysis.

This visual focus:

- Enhances reader engagement.
- Provides a comprehensive understanding of design objects.
- Inspires designers and enthusiasts alike.

Influence and Legacy

Educational Impact

Charlotte and Peter Fiell?s work has become standard reading in design education worldwide. Their books are frequently cited in university courses on design history, industrial design, and visual culture.

Their clear explanations and rich visuals make complex subject matter accessible to students and newcomers to the field.

Inspiring Contemporary Designers

Many modern designers cite the Fiells? publications as sources of inspiration. Their detailed case studies and historical insights help emerging designers appreciate the roots of their craft and the evolution of design principles.

Promoting Design Awareness

Through their exhibitions and writings, the Fiells have helped raise public awareness about the importance of design in everyday life. They emphasize that good design is not only functional but also culturally meaningful and aesthetically compelling.

Notable Awards and Recognitions

Over the years, Charlotte and Peter Fiell have received numerous accolades for their contributions to design scholarship and publishing, including:

- Design awards from major institutions.
- Recognition for their influence in curatorial practices.
- Honorary mentions for promoting design literacy worldwide.

Conclusion

Charlotte and Peter Fiell are pivotal figures in the understanding and appreciation of design. Their work bridges scholarly research and popular engagement, making complex design histories accessible and compelling. Whether through their meticulously researched books, inspiring exhibitions, or educational initiatives, they continue to shape the discourse around design?s role in culture and society. For anyone interested in the evolution of design or seeking to deepen their appreciation of creative innovation, exploring the work of Charlotte and Peter Fiell offers valuable insights and inspiration.

Keywords: Charlotte and Peter Fiell, design history, design books, design exhibitions, influential designers, contemporary design, visual culture, design education, industrial design, furniture design,

lighting design

Charlotte and Peter Fiell are renowned names in the world of design, architecture, and contemporary culture. Their collaborative work as authors, curators, and commentators has significantly shaped how audiences engage with design history and innovation. This dynamic duo's influence extends across numerous publications, exhibitions, and educational initiatives, making them pivotal figures for anyone interested in the evolution of design and its cultural implications. In this guide, we?ll explore their backgrounds, key contributions, notable publications, and the enduring impact they have had on the field of design.

Who Are Charlotte and Peter Fiell?

Charlotte and Peter Fiell are a married couple with a shared passion for design. Their combined expertise spans decades, during which they have authored influential books, curated exhibitions, and contributed to scholarly discussions on design?s role in society. Their work often blurs the lines between academic analysis and accessible storytelling, making complex topics approachable for both specialists and general readers.

Backgrounds and Expertise

- Charlotte Fiell: Charlotte has a background rooted in design history and cultural studies. Her focus often emphasizes contemporary design movements and their socio-cultural contexts.

- Peter Fiell: With a robust background in industrial design and architecture, Peter?s insights frequently delve into design innovation, craftsmanship, and technological advancements.

Together, their complementary skills allow them to craft comprehensive narratives that contextualize design within broader historical, technological, and cultural frameworks.

Major Contributions and Notable Works

Influential Publications

The Fiell couple has authored and edited numerous books that have become staples in the fields of design and architecture. Some of their most notable publications include:

- "1000 Chairs" (2002): An exhaustive survey of chair design, exploring its evolution from functional object to icon of style and artistic expression.

- "Design of the 20th Century" (1999): A comprehensive overview of the century's most influential designers, movements, and innovations.

- "The Story of Design" (2012): A richly illustrated narrative tracing the history of design from prehistory to the digital age.

- "Fashion Design": Exploring the trajectory of fashion as an integral aspect of cultural expression and innovation.

- "The FIELL Collection": A series highlighting iconic design pieces, offering insights into their creation and significance.

Curatorial and Exhibition Work

Beyond their writing, Charlotte and Peter Fiell have curated numerous exhibitions showcasing design history and contemporary innovation. Their curatorial approach often emphasizes storytelling, contextualizing objects within cultural and societal shifts.

Educational Impact

Their work has been influential in academic settings, inspiring curricula, lectures, and seminars that introduce students and professionals alike to the richness of design history.

The Fiell Approach to Design

The Fiell duo?s methodology combines rigorous research with engaging storytelling. They aim to:

- Make Design Accessible: Simplify complex concepts without sacrificing depth, making design history approachable for a broad audience.

- Highlight Cultural Contexts: Emphasize how design reflects, influences, and responds to societal changes.

- Showcase Innovation: Celebrate the creative process behind iconic objects, emphasizing craftsmanship, technology, and artistic vision.

- Foster Appreciation for Craftsmanship: Recognize the skill and artistry involved in design, encouraging respect for both historical and contemporary designers.

Key Themes in Their Work

- The Evolution of Design

Charlotte and Peter Fiell trace how design has evolved over centuries, influenced by technological advancements, cultural shifts, and economic factors. From early craftsmanship to mass production and digital design, they highlight pivotal moments and figures.

- The Intersection of Art and Function

Their work often explores how functional objects become symbols of aesthetic movement, reflecting societal values and individual identity.

- Sustainability and Future Trends

Recent writings emphasize the importance of sustainable design and innovation in addressing global challenges, positioning the Fiell couple as forward-thinking commentators.

- Design as a Cultural Phenomenon

They argue that design is not merely about objects but is deeply intertwined with cultural narratives, politics, and social change.

Influence and Legacy

Charlotte and Peter Fiell have played a crucial role in elevating the discourse around design, blending scholarly rigor with popular appeal. Their publications are widely used in academic courses, while their exhibitions and public talks inspire a broader appreciation for design?s role in shaping human experience.

Key Contributions to the Field

- Bridging Academic and Popular Audiences: Their work makes scholarly insights accessible,

fostering a wider appreciation.

- Documenting Design History: Their comprehensive catalogs serve as essential references.

- Encouraging Critical Engagement: They challenge audiences to consider design?s impact on society and the environment.

Conclusion: The Enduring Impact of Charlotte and Peter Fiell

In sum, Charlotte and Peter Fiell have established themselves as influential voices in the study and celebration of design. Their collaborative efforts have produced a body of work that is both academically rigorous and broadly accessible, shaping how we understand the history, present, and future of design. Whether through their books, exhibitions, or lectures, they continue to inspire new generations of designers, historians, and enthusiasts to appreciate the artistry, innovation, and cultural significance of design objects and movements.

Their legacy underscores the idea that design is not just about aesthetics but a vital part of human culture?an ongoing dialogue between function, form, and society. As the world faces new challenges and opportunities, the insights and enthusiasm of Charlotte and Peter Fiell remain vital sources of inspiration and knowledge in the ever-evolving landscape of design.

QuestionAnswer Who are Charlotte and Peter Fiell in the design world? Charlotte and Peter Fiell are renowned design historians, authors, and curators known for their influential books and contributions to design education and appreciation. What are some notable works by Charlotte and Peter Fiell? Their notable works include 'Design of the 20th Century', 'Furniture Design', and 'The Story of Graphic Design', which are widely regarded as essential references in the field. How have Charlotte and Peter Fiell influenced design history? Through their comprehensive publications and exhibitions, they have significantly shaped the understanding and appreciation of modern and contemporary design worldwide. Are Charlotte and Peter Fiell involved in any design exhibitions? Yes, they have curated numerous exhibitions on design topics, showcasing their expertise and promoting design awareness in museums and galleries globally. What is the focus of Charlotte and Peter Fiell's writing? Their writing primarily focuses on the history, evolution, and cultural impact of design, covering areas like furniture, graphic design, and industrial design. Have Charlotte and Peter Fiell received any awards for their work? Yes, they have received several awards and honors recognizing their contributions to design scholarship and publishing. Are Charlotte and Peter Fiell involved in teaching or academic work? While primarily known as authors and curators, they have also contributed to academic programs and lectures related to design history. Where can I find the works of Charlotte and Peter Fiell? Their books are available in major bookstores, online retailers, and libraries, and their exhibitions have been held at prominent museums worldwide. What impact

have Charlotte and Peter Fiell had on design education? They have influenced design education by providing comprehensive resources and inspiring new generations of designers and historians. Are Charlotte and Peter Fiell still active in the design community? As of the latest information, they continue to contribute through writing, curating, and participating in design discussions and events.

Related keywords: design, architecture, interior design, furniture, lighting, visual inspiration, design authors, modern design, Scandinavian design, design books

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