



Research Reactor

University of Missouri

IMPROVING MURR ANTI-SIPHON CONTROL SYSTEM RELIABILITY

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Reactor Engineer IV

MURR TURNS 60

Went critical early evening 13 OCT 1966

Routine operation at 5 MW 30 JUN 1967

10 MW power upgrade in 1974

Routine operation at 150 hr/wk in 1977

18

Time	Date 10/13/66
1712	Rod run-in due Rod "B" dropped at 11:11 AM Increase Rod "B" to 120 MA 1st under
1707	Withdrawing rods
1718	Rod "B" dropped at 12.62" rod run-in Raise Rod "B" M.A. count to 130 MA
1730	Withdrawing rods
1745	Seemed withdrawing rods
1750	seemed ki-power ch. #4 switching range switch.
1757	Withdrawing rods
1804	Reactor critical, Rod pos. "A" 17.00 " " "B" 17.18 " " "C" 17.27 " " "D" 17.55 Reg. Blade 4.99

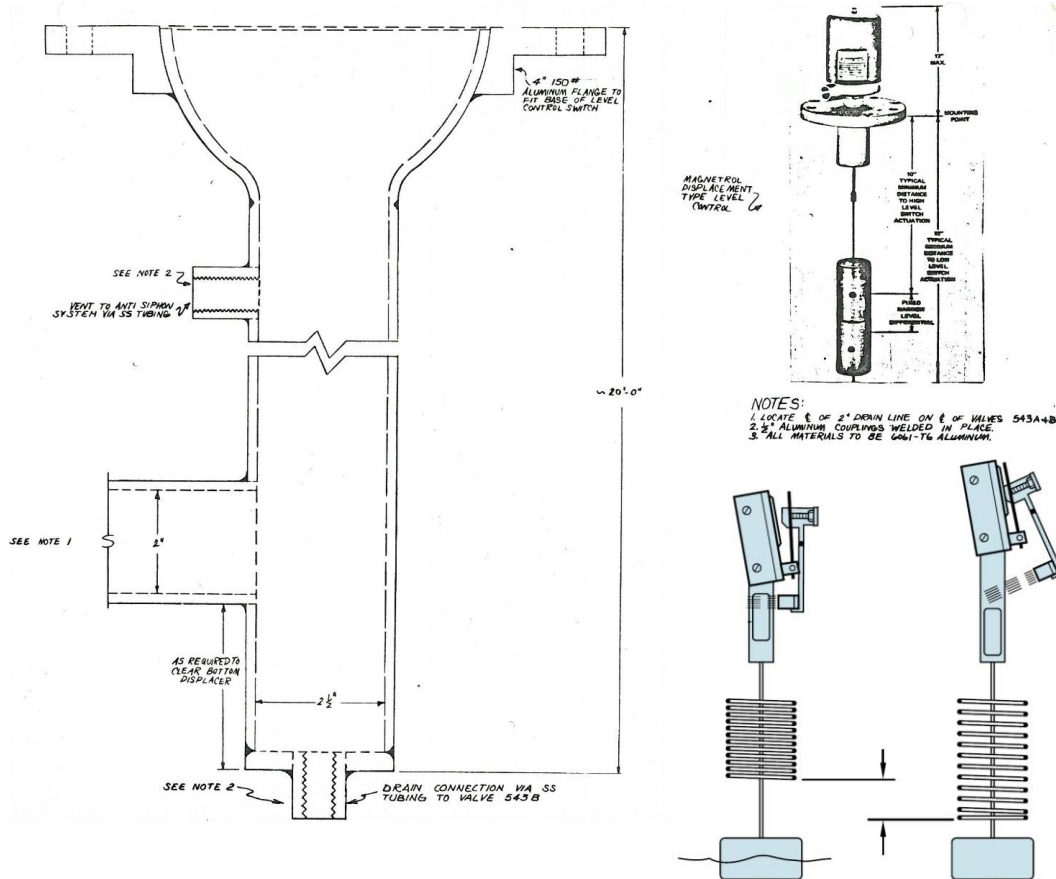


CA 1974

- [illegible]

Primary Connection
Drywell
Drain line

ANTI-SIPHON LEVEL CONTROLLER

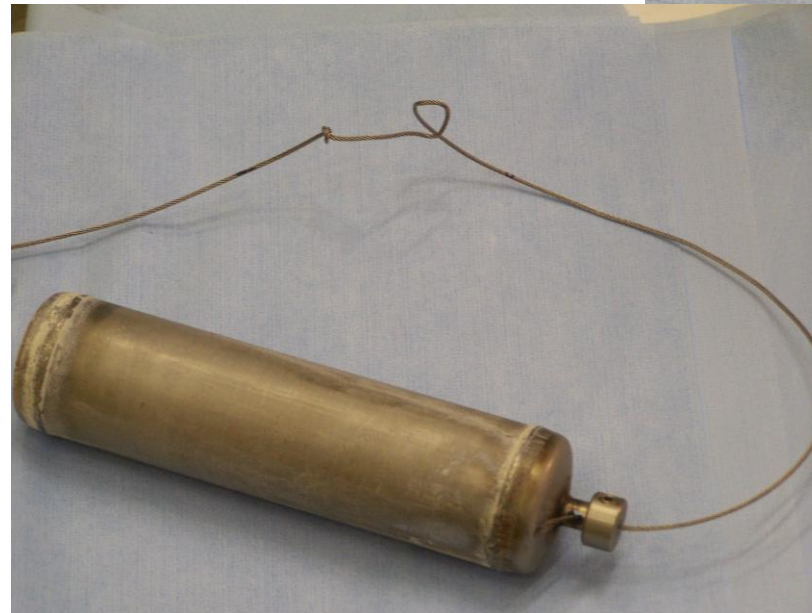
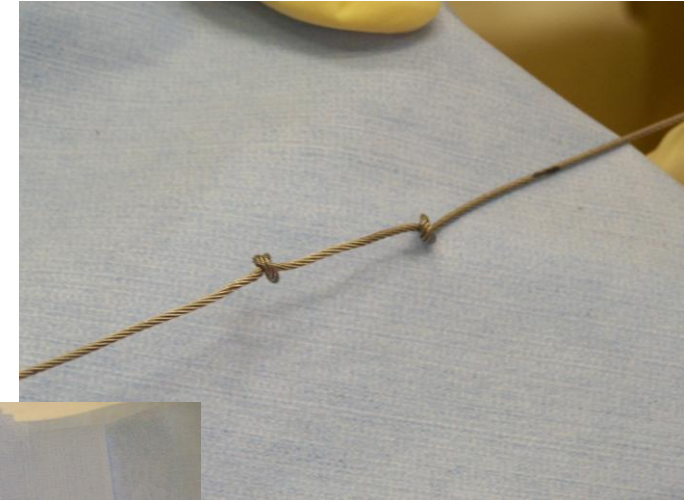


- Level controller 965 (LC965)
 - A drywell, a level switch, and control relays in RRI system
 - Drywell: 2 1/2" SCH40 aluminum pipe ~ 17 ft in length
 - Connected to anti-siphon system via 2" horizontal pipe, center-aligned to V543
- Magnetrol A15 device
 - Displacement style level sensor
 - Magnetic latching dry contact switch
 - In continuous service since 1974

WHAT HAPPENED

Displacer suspension cable developed knots.

Problem: knots in cable cause displacer to ride higher in drywell, potentially driving RRI at higher-than-TS setpoint



ML21327A304

Enclosure
U.S. Nuclear Regulatory Commission
November 23, 2021

Licensee Event Report No. 21-03 – November 9, 2021
University of Missouri Research Reactor

Introduction

On November 8, 2021, while the reactor was shut down for scheduled routine maintenance and Technical Specification (TS) surveillance testing on the anti-siphon system high level rod run-in instrument channel (level controller LC 965 instrument channel), the surveillance testing provided a measurement greater than the compliance procedure allowed for activation of the anti-siphon system high water level rod rod-in function. However, it was unknown on November 8 if exceeding the compliance procedure limit directly

WHAT THE TECH-SPEC SAYS

TS 3.2.f The reactor **shall not be operated unless the following rod run-in functions are operable**. Each of the rod run-in functions shall have 1/N logic where N is the number of instrument channels required for the corresponding mode of operation.

		Number Required (N)			Trip Set Point
	Rod Run-In Function	Mode I	Mode II	Mode III	
6	Anti-Siphon System High Level	1	1	1 ⁽¹⁾	6 inches above valves (Max)

⁽¹⁾ These Instrument Channels are not required when in Mode III operation below 50 kW in natural convection cooling (natural convection flange and pressure vessel cover removed). These Instrument Channels are required when in Mode III operation with forced cooling.

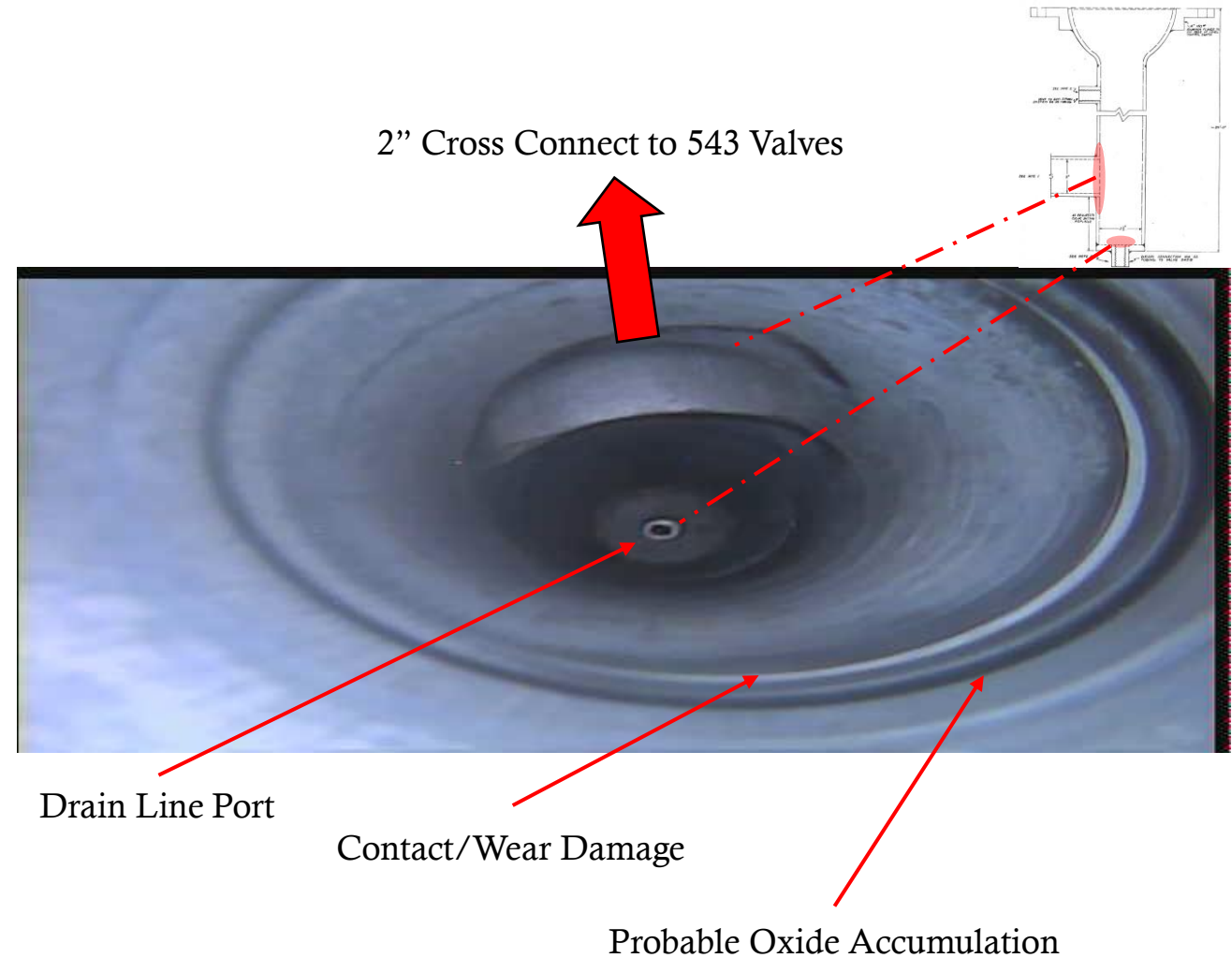
Problem: “*6 inches above valves (Max)*” is ambiguous for an engineer

WHAT ELSE DOES THE HARDWARE SAY?

Significant wear and damage to inner surface of LC965 standpipe

Problem: stainless steel displacer is striking aluminum pipe wall; work hardening and cracking increasingly possible

Cause: fluid movement when primary coolant is secured; displacer is driven into standpipe by lateral surge



WE WANT A NEW SOLUTION

- Non-contact level sensor
 - Eliminates cable knots
 - Eliminates standpipe wear and tear
- Constraint: pressure rating
 - Tolerate 36 psig with safety factor
 - Separates safety function (fission product barrier) from control function (level sensing)
- Dry-contact outputs
 - No change to existing control system electronics

~~PLAN A~~

PLAN B

PLAN C

POTENTIAL SOLUTION: LASER TOF SENSOR

Laser Time of Flight (TOF) non-contact level sensor

- Maximum measurement distance set by beam divergence and time between light pulses
- Distance resolution set by timing precision

$$z = \frac{c \cdot \Delta t}{2}$$

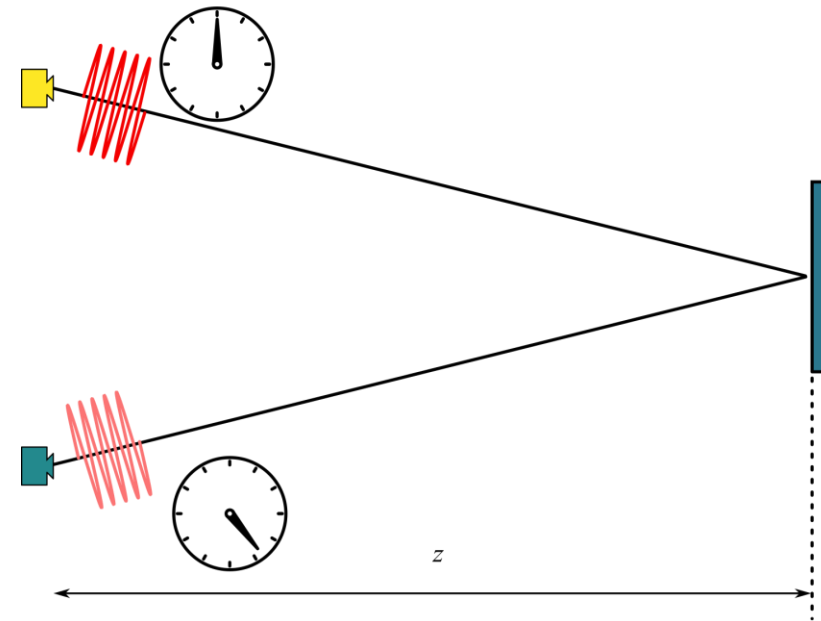
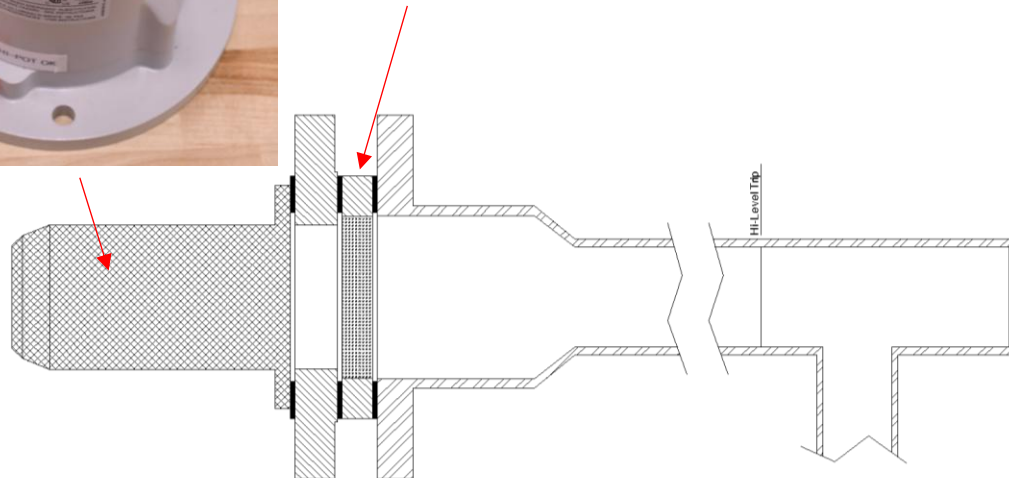


ABB LM80



✓ Fission Product Barrier

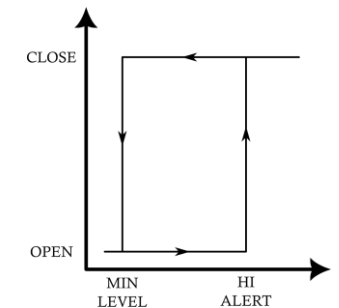
- J.M. Canty pressure-rated optical viewport
- FM certified to 150 psig and 450 °F

✓ Control System Input

- Programmable OPEN and CLOSE distances
- Bistable hysteresis eliminates switch flutter

✓ Laser system specifications

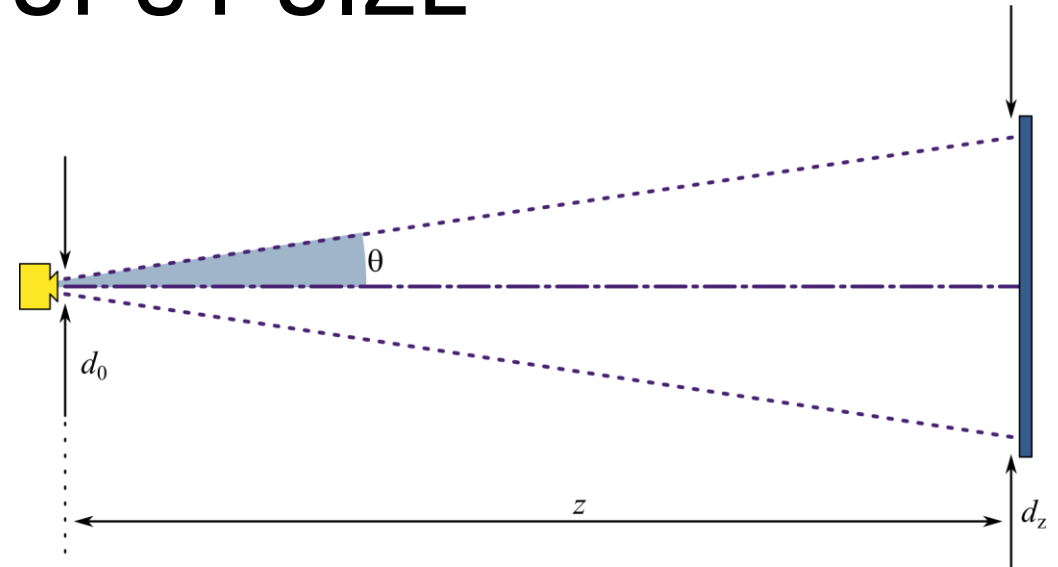
- $\lambda = 908 \text{ nm}$
- $\theta \leq 0.3^\circ$
- $d_0 = 20 \text{ mm}$



COMPLICATION #1: BEAM SPOT SIZE

- Beam diverges as it travels
- Spot size at target d_z a function of
 - Initial beam diameter d_0
 - Beam divergence θ
 - Distance traveled z
- If d_z too great, beam intercepts pipe wall and potentially spoils measurement

$$d_z \approx 2.79 \text{ in}$$

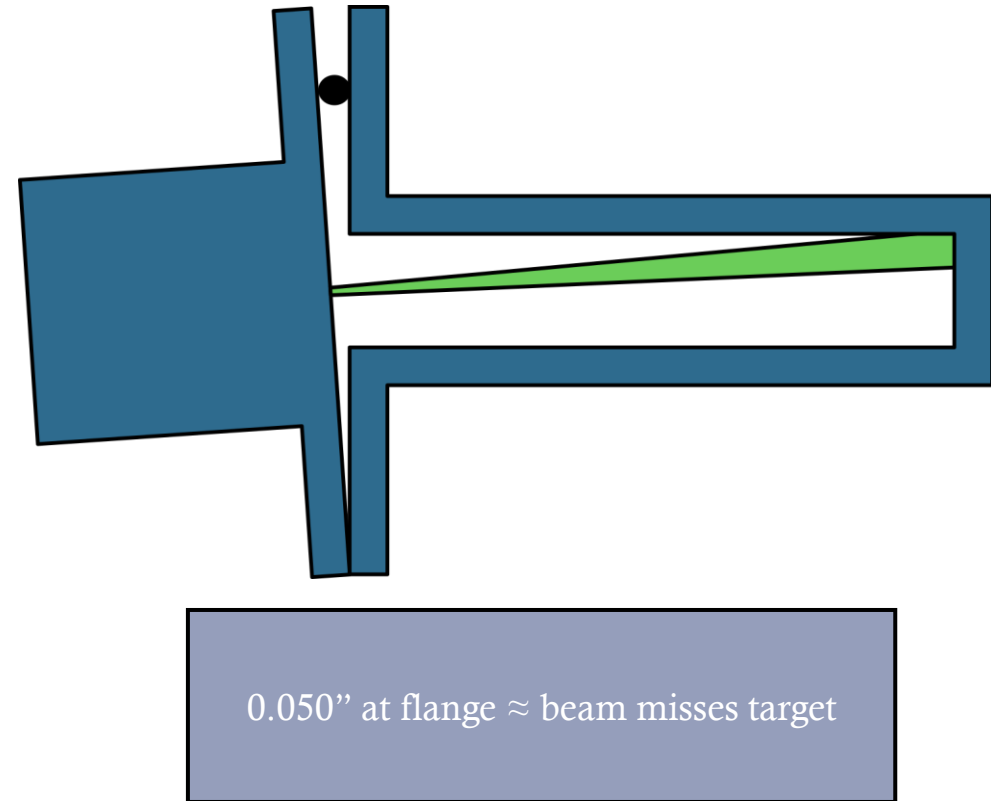


$$d(z) \cong 2(r_0 + z \tan \theta)$$

Parameter	Value	Unit
d_0	20	mm
θ	0.3	°
z	192	in

COMPLICATION #2: BEAM MISALIGNMENT

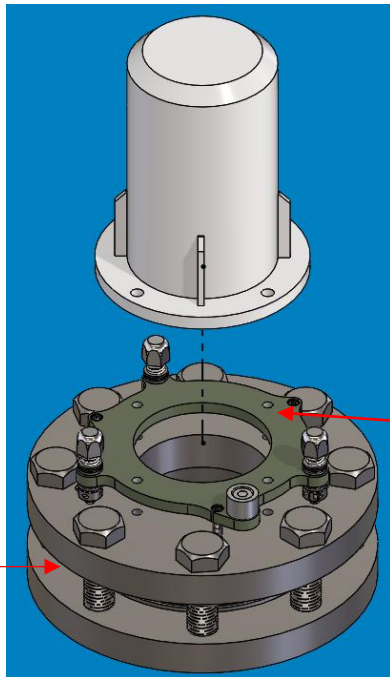
- Field-welded standpipe flange
 - Horizontal parallelism not guaranteed
- Asymmetric laser / photodiode on LM80
- Perfect alignment preferred
 - Angular deviation sends beam into drywell pipe wall
 - Laser should be centered on drywell axis, but it won't be



PERPENDICULAR ALIGNMENT



Leica GB322



Rated Viewport

- Alignment via custom tribrach
 - Surveyor's device used to achieve level on uncertain surfaces
 - Tri-point fixture with integrated bubble level
 - Minute to sub-minute accuracy potential
- Fixture features:
 - Ultrafine thread jack screws
 - Custom split-nut screw locks
 - Spherical contact leveling washers

VALIDATION TESTING

Done So Far

- Preliminary tribrach design

Remaining to Do

- Drywell mockup testing with PVC model
 - Alignment setting precision
 - Beam spot size at half / full distances
 - Programmable relay contact state / failed-state testing
 - Relay transition repeatability
 - Temperature stability testing ($T \leq 120$ °F)
 - More?
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