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"Theoretical Analysis and Fabrication of Portable Archimedes Screw Micro Hydro Generator"

SHASHANK.L, GOKUL.R, RAJATH.N.R,SATWIK BHAT.S

STUDENT, MECHANICAL, K.S.I.T, BANGALORE, INDIA
STUDENT, MECHANICAL, K.S.I.T, BANGALORE, INDIA
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STUDENT, MECHANICAL, K.S.I.T, BANGALORE, INDIA

ABSTRACT: This paper intends to check the screw rotary engine rotor for remote space electricity production. The analysis is finished by examining theoretical calculation to experimental results. The performance of Archimedes water turbines that has completely different blade numbers that square measure evaluated to get correct blade configuration. Varied losses within the system square measure mentioned, showing that the experimental power outputs and theoretical predictions have variations. The micro-hydro power station supported by Archimedes Screw could be a form of renewable energy power station that additionally operates at low prices. It needs no reservoir to power the rotary engine. The water can run straight through the rotary engine and into the stream or stream to use it for the opposite functions. This features the lowest environmental impact on the native scheme.

KEYWORDS: ARCHIMEDES SCREW,LOW FLOW RATE,LOW COSTS

I. INTRODUCTION

A) Archimedes Screw

It is believed that the Archimedes screw was fancied by Archimedes of Syracuse (287-212 BC), the Greek man of science, scientist, and creator. It is an associated ancient technology that has seen abundant use throughout history for several completely different functions. Historically, the device was enforced as a pump, however a lot of recently it's been utilized as a hydroelectric generator.

Archimedes screws include a volute array of blades that wrap around a central diameter, very similar to a wood screw. The inner diameter could be a cylindrical extrusion that the blades square measure usually welded to. This screw is supported at intervals by a close mounted trough there's a little gap between the trough and screw that enables the screw to rotate freely whereas permitting solely a little quantity of water to leak past the blade edges.

B) Archimedes Screw Pump

Archimedes screws are used as water pumps for irrigation and de-watering for a protracted time. It is a machine used for transferring water from a low-lying body of water into irrigation ditches. Water is wired by turning a screw-shaped surface within a pipe. Archimedes screws also are used for materials like powders and grains.

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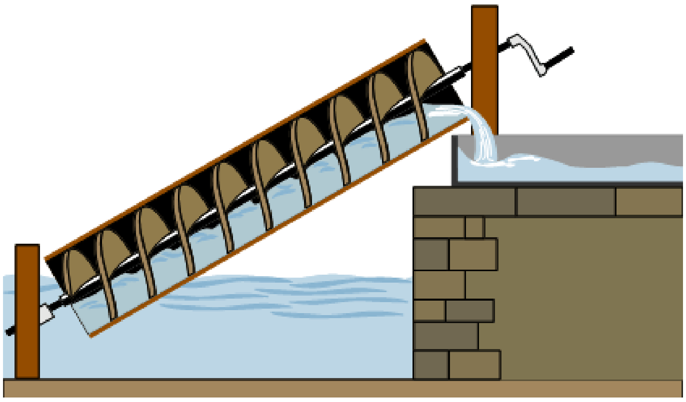
Fig 1.1 Archimedes Screw Pump[1]

C) CALCULATIONS & EXPECTED RESULTS

Terms and Ideal Conditions:

1. External Parameters
   a. Outer Radius (R_0)
   b. Total Length (L)
   c. Slope of Screw ($k = \tan\theta$)
2. Internal Parameters
   a. Inner Cylinder Radius (R_i) [$0< R_i< R_0$]
   b. Pitch (P) [$0<P<2*\pi* R_0/k$]
   c. Number of Blades (N) [N=1, 2, 3, 4…]

Maximum Value of Volume of Water in One Cycle:

$V_{Tmax} = V_T^* = \pi * R_0^{2*} P$ ----- (1)

Volume of One Chute:

$V_C = \pi * (R_0^2 – R_i^2) L / N$ ----- (2)

Volume of One Bucket:

$V_b = V_T / N$ ----- (3)

Dimensionless Parameters:

1. Radius Ratio, $\rho = R_i / R_0$ [$0 < \rho < 1$] ----- (4)
   Also, $R_i = \rho * R_0$
2. Pitch Ratio, $\lambda = k * P / 2 \pi R_0$ [$0 < \lambda < 1$] ----- (5)
   Also, $P = 2 \pi R_0 \lambda / k$
3. Volume Ratio, $\nu = V_T / \pi R_0^2 P$ [$0 < \nu < 1$] ----- (6)

Therefore, $\nu = V_T / V_{max}$

Value of ν depends on N, ρ, λ

Thus, ν can be written as ν (N, ρ, λ)

Therefore,

$V_T = (2 \pi R_0^3 / k) * \nu (N, \rho, \lambda)$ ----- (7)

$R_i = \rho^* * R_0$ ----- (8)

$P^* = 2 \pi R_0 \lambda^* / k$ ----- (9)

$V_T^* = 2 \pi R_0^3 / k$ ----- (10)

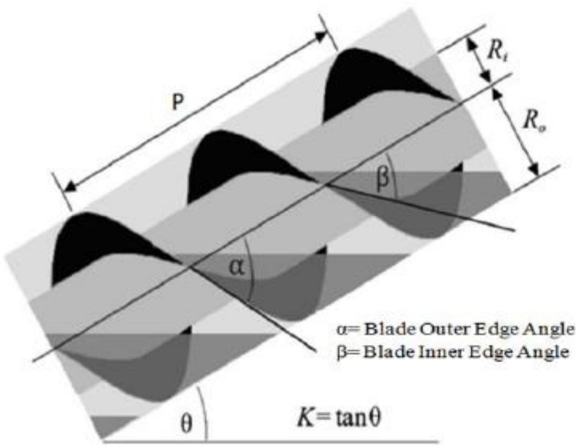

Fig 2.1 Angles in a Screw

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Finding Optimum Values of ρ, λ according to 'N'
To Find Efficiency:

Hydraulic Power Developed (P_{in}) = d g Q H ----- (11)

Where, d = Density of Water = 1000 kg/m^3

g = 9.81 m/s

Q = Discharge

H = Height of Waterfall = L sin θ

Output Power (P_{out}) = T W = T (2 π n) ----- (12)

Where, T = Torque Developed (N-m)

n = Rotational Speed (rev/s)

Efficiency (η) = P_{out} / P_{in} ----- (13)

Height/Head H = L sin θ = 300 mm * sin 20° = 102.6 mm

Input Power P_{in} = 1000 kg/m^3 * 9.81 m/s^2 * 0.1026 * Q

We have one unknown parameter Q, discharge of water that enters the turbine at the elevated inlet region of the Archimedes Screw turbine. There are many elements to be considered while measuring discharge. Namely: material of pipe, flow velocity of water, pressure in pipe and cross sectional area of pipe.

No of Blade (N)	Optimal radius ratio (ρ*)	Optimal pitch ratio (λ*)	Optimal volume per turn ratio (λ*υ(N,ρ*,λ*))	Optimal volume ratio (υ(N,ρ*,λ*))
1	0.5358	0.1285	0.0361	0.2811
2	0.5369	0.1863	0.0512	0.2747
3	0.5357	0.2217	0.0598	0.2697
4	0.5353	0.2456	0.0655	0.2667
5	0.5352	0.2630	0.0696	0.2647
6	0.5353	0.2763	0.0727	0.2631
7	0.5354	0.2869	0.0752	0.2619
8	0.5354	0.2957	0.0771	0.2609
9	0.5356	0.3029	0.0788	0.2601
10	0.5356	0.3092	0.0802	0.2592

Fig 2.2 Optimal Value Constants

Find values of R_i*, P*, V_T*, V_b*

Finding Discharge (Q):

Pipe Size (in)	Gravity to Low Pressure &6f/s Velocity (in GPM)	Pressure (20-120 PSI)&12f/s Velocity (in GPM)	Peak Pressure (>120 PSI)& 18f/s Velocity (in GPM)
1/2"	7	14	21
3/4"	11	23	36
1"	16	37	58
1.25"	25	62	100
1.5"	35	81	126
2"	55	127	200
2.5"	80	190	300
3"	140	273	425

Table 2.1 Discharge from Different Pipe Sizes

1 Gallon = 3.785 Litres

1 PSI = 6.9 kPa

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Assuming 60% efficiency, 6f/s velocity and gravity to low pressure

Pipe Size (in)	Discharge Q		Power P (in Watts)	
	GPM	LPM	Input P_{in}	Expected Output P_{th}
1"	16	60.56	1.02	0.61
1.5"	35	132.48	2.22	1.33
2"	55	208.18	3.49	2.09
2.5"	80	302.8	5.08	3.05
3"	140	529.9	8.89	5.33

Table 2.2 Power Output from Different Pipe Sizes

Pitch Calculations for 2 Blade Rotor (N=2):

$\rho^* = 0.5369$; $\lambda^* = 0.1863$

$R_0 = R_i / \rho$; $P^* = 2 \pi R_0 \lambda^* / k$

R_i=45mm	R_o=83.81mm
Angle of Inclination θ (degrees)	**Pitch (mm)**
15	366.13
20	269.54
25	210.39
30	169.92
35	140.11
40	116.92
45	98.1

Table 2.3 Inclination – Pitch (N=2, R_i = 45mm)

R_i = 50mm	R_o = 93.13mm
Angle of Inclination θ (degrees)	**Pitch (mm)**
15	406.85
20	299.51
25	233.78
30	188.82
35	155.69
40	129.92
45	109.01

Table 2.4 Inclination – Pitch (N=2, R_i = 50mm)

R_i = 55mm	R_o = 102.44mm
Angle of Inclination θ (degrees)	**Pitch (mm)**
15	447.52
20	329.45
25	257.15
30	207.69
35	171.25
40	142.9
45	119.91

Table 2.5 Inclination – Pitch (N=2, R_i = 55mm)

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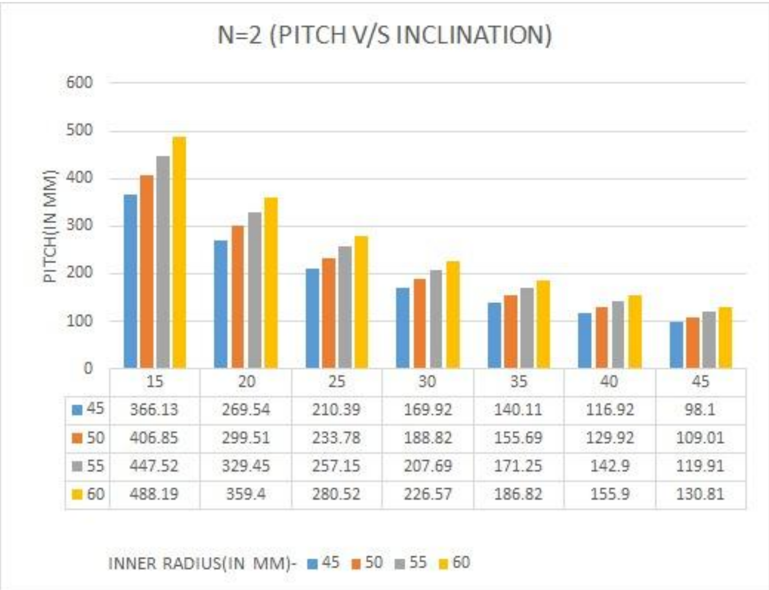
R_i = 60mm	R_o = 111.75 mm
Angle of Inclination θ (degrees)	**Pitch (mm)**
15	488.19
20	359.4
25	280.52
30	266.57
35	186.82
40	155.9
45	130.81

Table 2.6 Inclination – Pitch (N=2, R_i = 60mm)



The graph shows the representation of Pitch vs Inclination for a screw start of 2 (N=2). The different colours represent inner radii. The graph shows that the pitch decreases with increase in angle of inclination.

Fig 2.3 Pitch vs Inclination for N=2

Pitch Calculation for 3 Blade Rotor (N=3):

$\rho^* = 0.5357$; $\lambda^* = 0.2217$

$R_0 = R_i / \rho$; $P^* = 2 \pi R_0 \lambda^* / k$

R_i = 45mm	R_o = 84 mm
Angle of Inclination θ (degrees)	**Pitch (mm)**
15	436.69
20	321.48
25	250.93
30	202.67
35	167.11
40	139.45
45	117.01

Table 2.7 Inclination – Pitch (N=3, R_i = 45mm)

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R_i = 50mm	R_o = 93.34mm
Angle of Inclination θ (degrees)	**Pitch (mm)**
15	485.24
20	357.23
25	278.83
30	225.2
35	185.69
40	154.95
45	130.02

Table 2.8 Inclination – Pitch (N=3, R_i = 50mm)

R_i = 55mm	R_o = 102.67mm
Angle of Inclination θ (degrees)	**Pitch (mm)**
15	533.75
20	392.94
25	306.7
30	247.71
35	204.25
40	170.44
45	143.02

Table 2.9 Inclination – Pitch (N=3, R_i = 55mm)

R_i = 60mm	R_o = 112mm
Angle of Inclination θ (degrees)	**Pitch (mm)**
15	582.25
20	428.65
25	334.57
30	270.22
35	222.81
40	185.93
45	156.01

Table 2.10 Inclination – Pitch (N=3, R_i = 60mm)

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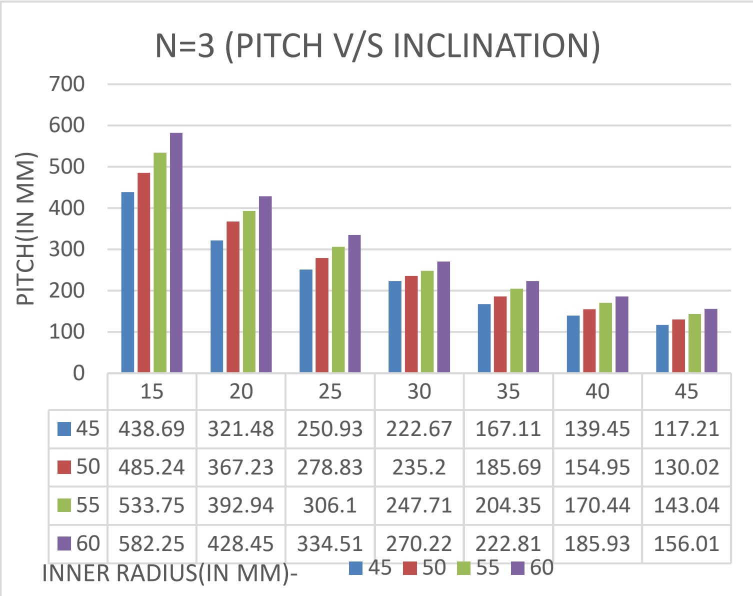


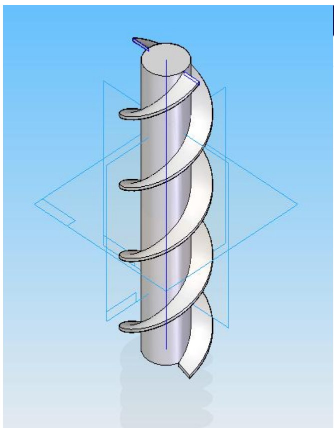
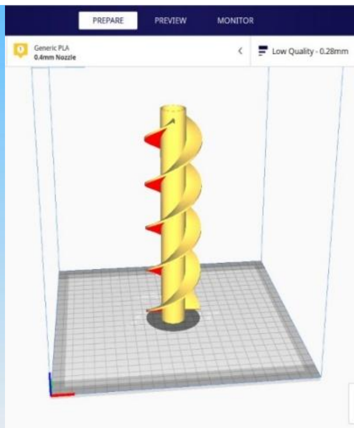
	15	20	25	30	35	40	45
45	438.69	321.48	250.93	222.67	167.11	139.45	117.21
50	485.24	367.23	278.83	235.2	185.69	154.95	130.02
55	533.75	392.94	306.1	247.71	204.35	170.44	143.04
60	582.25	428.45	334.51	270.22	222.81	185.93	156.01

Fig 2.4 Pitch vs Inclination for N=3[8, 14, 17]

The graph is the representation of Pitch vs Inclination for a screw start of 3 (N=3). The colours show different lengths of inner radii of the helical screw. From the graph, we can observe that the pitch decreases with increase in angle of inclination.

III. FABRICATION

For the fabrication part of the project we decided to go with additive manufacturing as our choice of manufacturing, due to the fact that our project has a very geometrical complex structure. Additive manufacturing allows this complex structure to be easily manufactured or produced. The material being used for making this product is polylactic acid also known as P.L.A., has very good mechanical properties making it a suitable choice for using it in this product. Properties such as the melting point tensile strength and also the cost made it a suitable option .Also the material is biodegradable in nature and hence it is also contributing in keeping the environment and other factors which are related in check .After the above calculations were completed a suitable dimension was selected and a model was made using CAD software fig 3.1. The fig 3.3 shows the manufacturing taking place, the CAED model is first converted into an S.T.L file format (fig 3.2) which is also called the standard triangulation language this language redraws the software using triangles and allows the 3D printer to read the model carefully .The model is then taken and resized accordingly and is then manufactured the finished product is shown in fig 3.4.

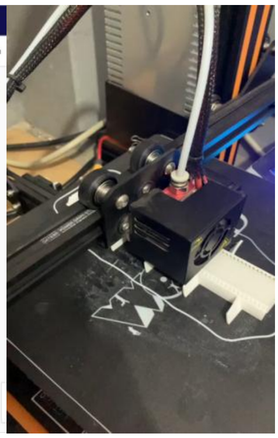


Fig 3.1 CAD Model **Fig 3.2 STL ModelFig 3.3 Manufacturing**

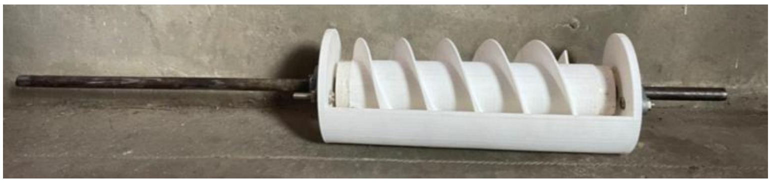


Fig 3.4 Finished product

IV. CONCLUSION

Based on the theoretical calculations, it was discovered that even minor changes in parameter values can result in significant changes in the screw's size. Inner radius, outer radius, pitch of the screw, total length of the screw, inclination to be placed in, and number of blades are the most important criteria. Fluid characteristics such as flow rate and velocity, in addition to blade dimensions, play a significant role in the generator's performance. As a result, the environment in which the generator is located is important. The pitch of the screw also varies with the inclination that the generator is to be placed in. For the ideal dimensions, it is important to consider all parameters that affect the outcome and performance of the generator.

We need to know the flow rate of water entering the generator in order to compute the theoretical power output. We took discharges from various pipe sizes into account while calculating flow rate. We discovered that discharge is impacted not only by pipe diameter, but also by the velocity of water passing through the pipes and the pressure built up within the pipes. These values lead to determining the theoretical power output in watts. A pipe with a 1 inch diameter can give us a discharge up to 60lpm which would in turn provide us with 0.61W of power. Similarly, pipes of 1.5in, 2in, 2.5in and 3in diameters can discharge 132lpm, 208lpm, 302lpm and 530lpm respectively. These discharges from the variety of pipe sizes can theoretically supply us 1.33W, 2.1W, 3.05W and 5.33W respectively. An efficiency of 60% was assumed in the calculations performed.

Machining or casting could have been used for manufacturing. However, we came to the conclusion that 3D printing was the optimum method for building our generator. In comparison to machining and casting, 3D printing offers a greater choice of components manufacturing options, the ability to print minute features accurately, and lower costs. It is more environmentally friendly, uses less energy, takes less time to make parts and cost effective. Another reason we chose this technique of production is that it makes use of PLA. Polylactic acid is not only a stiff material after it cools and solidifies; it is also biodegradable, as it is made of corn starch, and thus does not contaminate the environment in any way. Since PLA filament has a low melting point and does not require much electricity to melt, it does not emit fumes or pollute the workspace.

Advantages of Archimedes Screw Generator

1. **Environment Friendly:**
   Archimedes Screw Generators square measure one among the foremost atmosphere friendly turbines. Being reservoir or dam-less there's no likelihood of flash floods close to the location. Thus, the installation of Archimedes Screw Generators won't affect the encompassing. Also, natural vegetation close is unaffected, therefore there'll be no decomposition of this natural vegetation which may result in the formation of the greenhouse emission gas that is primarily chargeable for the climate changes, therefore, reducing the carbonic acid gas level. Once it involves small Archimedes Screw Generators that square measure used for domestic functions, there's no would like of a reservoir or a lot of houses
2. **Easy Set-up and Implementation:**
   It can be easily set up in small canals, ponds, rivers and even streams as the head requirement is not much (1m-10m). It also requires less maintenance and operational cost and it is easy to install as not much parts are there, thus reducing the civil work. Specifically, a micro hydro screw generator which is used for domestic and personal

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purposes is even easier to maintain. The parts are easy to replace, have high availability and comparatively less costly.

3. **Durability:**
The Archimedes Screw Generators is taken into account as reliable due to its high sturdiness. A good quality Archimedes Screw Generator contains a style lifetime of thirty years and more this will be extended with a serious overhaul that features re-tipping the screw flights. the damage and tear of the rotary engine are additionally less. For the 3D micro-scale generator that is created of PLA, sturdiness is higher once as compared with larger-scale generators thanks to the water flow being slow for dealing permanent harm to the generator or any of its elements.

4. **Sensible and Efficient:**
The Archimedes Screw Generator will simply manufacture up to eighty-fifth mechanical potency and has 100% meter potency as all the water that enters the generator exits it. ASGs is put in multiple environments and might still give a minimum of hr mechanical potency.

5. **Variable Speed Operation (Self Regulating):**
The speed of the screw is raised or shrivelled reckoning on the flow offered within the stream. this is often far better than having a fixed-speed screw and ranging the flow through an automatic sluice, which creates high head losses and impacts the general system potency. Variable-speed screws also are quieter operational and don't suffer from 'back slap' at the discharge end of the screw.

6. **Price Effective:**
The speed of the screw is raised or shrivelled reckoning on the flow offered within the stream. this is often far better than having a fixed-speed screw and ranging the flow through an automatic sluice, which creates high head losses and impacts the general system potency. Variable-speed screws also are quieter operational and don't suffer from 'back slap' at the discharge end of the screw.

7. **Scale-able:**
This is the most important advantage of Archimedes Screw Generators. Theycan be made at any size according to the landscape, which implies space required for building and set-up of the generator is decreased to satisfy power needs. The Archimedes Screw generators vary from massive scale high power generation to little scale low power generation for domestic and private desires. Creating it smaller means that creating it straightforward to hold around and store. The first reason for a tiny low scale generator is to create it accessible and customary in each ménage

V. FUTURE SCOPE

A) Small-scale Power Generation:
Archimedes Screw generators are employed for large-scale power generation in many parts of the world. These generators can also operate at low head and flow rates, allowing them to be made on a small scale and producing low-intensity electricity.

B) Integration of ASGs and Rainwater Harvesting System:
Because small-scale ASGs only require a reasonable stream of water, they can be utilised in practically any household as their popularity grows. Rainwater harvesting systems are currently installed in the majority of urban homes. The primary rainwater pipe can be fitted with an ASG, which can create low-intensity power. Even if such generators can only produce a tiny amount of power, collecting and storing the energy in batteries can help provide electricity to small structures in the event of a power outage. A metaphorical saying would be, "Little drops of water make the mighty ocean". As a result, ASGs can serve as a source of backup power for buildings.

C) Archimedes Screw Generators as UPS Systems:
When there is a regular power supply, UPS systems charge up and store the electricity for when there is a power outage. Any consumer would benefit from having this system. A good UPS, on the other hand, uses up to 150 watts to charge itself at full load and does it in a relatively short time. It would

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take time to charge a battery using an unconventional power generation technology like ASGs, but once set up, it would be far more cost effective.

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