A power plant to be built on a river having rate of flow of 67 m3/s and utilizing 12.8 m of head. The speed fixed by the electrical company is 180 rpm. The efficiency of the turbine is 90%. It is further seen that the specific speed of 342 rpm would be best for the hydro plant. Selection of water turbine is to be made from the following data meant for the required specific speed and calculated for the unit speed.

Diameter of the runner (cm)	137.5	145	152.5	160	167.5
Unit Speed in rpm	49.5	47	44.6	42.5	40.6
Unit Power in kW	35.4	39.5	43.6	48.1	53.7

Find out (i) the type of the turbine (ii) number of the turbine required (iii) diameter of the runner based upon unit power.

H =	12.8	m
Qtotal=	67	m^3/s
N=	180	rpm
Ns=	342	
nt=	90	%

from specific speed Ns= NP^0.5/H^5/4

Pt per turbine =	2116.1	kW
Unit power Pu =	46.21	kW/m^1.5
unit speed Nu=	50.3	rpm/m^0.5

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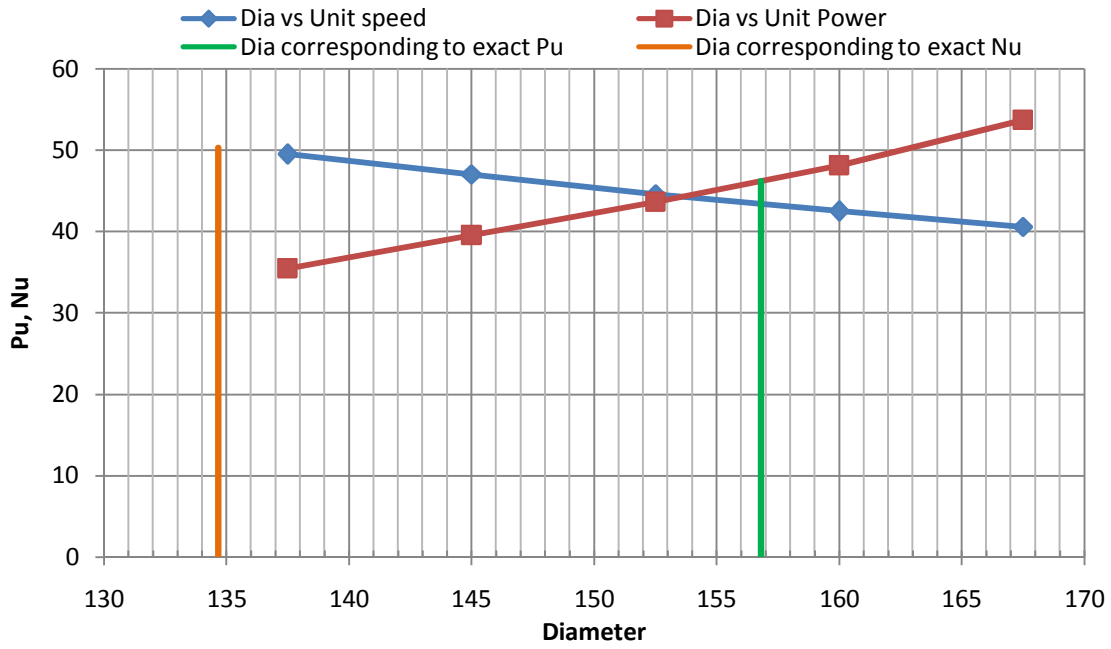
Type of the runner is **Kaplan**

IF(Ns>=225,"Kaplan",IF(Ns>=51,"Francis","Pelton"))

Per Turbine discharge Q = 18.725 m^3/s ($Pt=\eta_t \gamma QH$)

Number of Unit = (Q_{total}/Q) **3.5782 approx** **4** 4



for the above unit power (Pu) diameter of the runner can be calculated from the above table

156.8 cm

	before	after
dia(cm)	152.5	160.0
Pt(kW)	43.6	48.12

graph (Pu)

156.80	0
156.80	46.21

for the above unit speed (Nu) diameter of the runner can be calculated from the above table

134.65 cm

	before	after
dia(cm)	145	152.5
Ns	47.0	44.60

graph (Nu)

134.65	0
134.65	50.31

2. The result of a test on water turbines operating at full gate opening under a head of 5.28 m are given as follows:

Unit Speed	65.4	72.6	76.3	79.9	83.5	87.2	90.75	94.4
Q (m^3/sec)	3.74	3.66	3.6	3.56	3.51	3.45	3.39	3.32
Unit power in kW	12.53	12.87	13.00	13.02	12.92	12.73	12.38	11.94

Plot graphs of unit power (kW) and efficiency against unit speed. If the turbine runs at a speed of 200 rpm, find the power and efficiency. If the head is increased to 5.8 m, the speed remains the same, find the corresponding power and efficiency.

1 hp = 0.746 kW

Given:

H=	5.28	m
N=	200	rpm
new H=	5.8	m

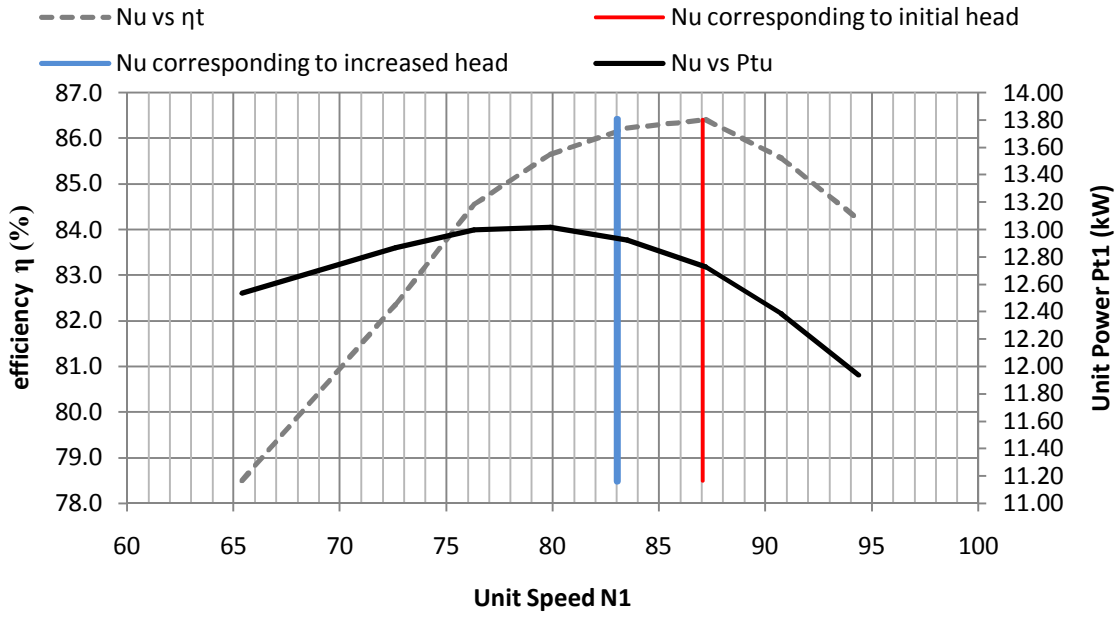
γ= 9810 N/m^3 or 1000 when in HP

turbine output Pt = Pu*H^3/2

turbine available power Pa = γQH (W) or Pa (HP) = γQH/75

Turbine efficiency ηt=(Pt/Pa) (=1000*(Pu*H^0.5)/γQ) (=75*(Pu*H^0.5)/γQ)

ηt	78.5	82.4	84.6	85.7	86.2	86.4	85.6	84.2



When N= 200 rpm

unit speed N_u= **87.0** rpm

find values of unit power Pt1 and efficiency ηt from figure

graph (initial head)

87.0	78.5
87.0	86.4

unit power P_{tu} =	**12.5**	kW/m^1.5		
Turbine output P_t =	151.7	kW	or	203.3 HP
efficiency η_t=	**83.5**	%		

if head is increased

graph (increased head)

83.0	78.5
83.0	86.4

H =	5.8	m
When N=	200	rpm
unit speed N_u=	**83.0**	rpm

find values of unit power Pt1 and efficiency ηt from figure

unit power P_{tu} =	12.9	kW/m^1.5		
Turbine output P_t =	180.2	kW	or	241.5 HP
efficiency η_t=	86.2	%		

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The head water surface and tail water surface levels in a water turbine installation are 51 m and 45 m above sea level respectively. The turbine is designed to run at a uniform speed of 75 rpm under all conditions. The manufacturer's test under a head of 7.5 m shows that the turbine develops 1500 kW at its maximum efficiency of 87%. The computed values of unit speed and unit power in percentage of normal values and the efficiency η in percentage of the maximum efficiency are tabulated below:

Unit Speed in % of normal value	65.4	70	80	90	100	110	120	130
Unit power in % of normal value	73.5	82.2	90	96.5	100	99.5	99	90
efficiency η in % of normal value	85	88	94	98	100	99	94	85

Calculate the power and discharge of the turbine under normal working conditions.

Given:

1 hp = 0.746 kW

H_{test}=	7.5	m	
Pt_{test}	1500	kW	
$\eta_{testmax}$	87	%	
head water surface	51	m	
tail water surface	45	m	
design N_{Normal}	75	rpm	
γ=	9810	N/m^3	or 1000 when in HP

turbine output Pt = Pu*H^3/2

turbine available power Pa = γQH (W) or Pa (HP) = γQH/75

Turbine efficiency $\eta_t=(P_t/Pa)$ (=1000*(Pu*H^0.5)/γQ) (=75*(Pu*H^0.5)/γQ)

tested unit power P_{utest}=	73.0	kW/m^1.5
tested unit speed N_{utest}=	27.4	rpm/m^0.5
Normal working head H_{normal} =	6	m

Normal unit speed $N_{uNormal}$ = 30.6 rpm/m^0.5

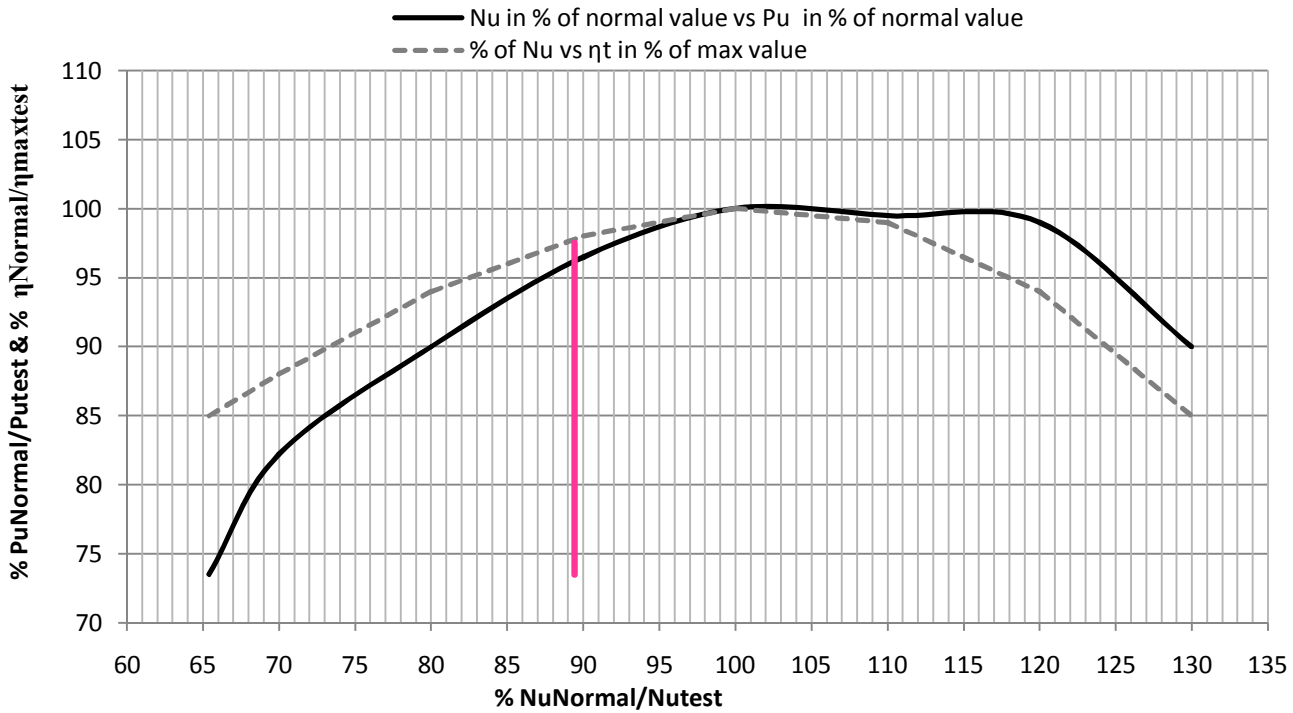
% of tested unit speed $N_{utest}/N_{uNormal}$= 89.4 %

efficiency η in % of normal value cooresponding to graph $\eta_{test}/\eta_{Normal}$ 96 %

Unit power in % of normal value cooresponding to graph $P_{utest}/P_{uNormal}$ 97.5 %

graph plot

89.4	73.5
89.4	97.5



Normal unit power $P_{uNormal}$ = 74.9 kW/m^1.5

normal efficiency η_{normal}= 90.6 %

P_{normal} = ($P_{uNormal}$*H^1.5) 1100.8 kW

Q_{normal}= (P_{normal}*1000/γ$\eta_{Normal}H_{normal}$) 20.6 m^3/s

A small hydro development, a Kaplan turbine runs under a head of 2.1m. It has a runner of 3.5 m diameter and develops 600 kW at 80 r.p.m. Determine the discharge and specific speed of the machine assuming an overall efficiency of 80%. If a homogeneous turbine is to be tested at a head of 3.0 m and diameter 1.5 m, what are the rotational speed, discharge and power of the unit?

H_p=	2.1	m	p- for prototype
η_{op}=	80	%	m- for model
P_p=	600	kW	
N_p=	80	rpm	
D_p=	3.5	m	
D_m=	1.5	m	
H_m=	3	m	

Q_p=	36.406	m3/s
Ns_p=	775.16	

for homogeneous turbine,

N_m=	**223.11**	**rpm**	using	$(gH/N^2D^2)_m=(gH/N^2D^2)_p$
Q_m=	**7.99**	**m3/s**	using	$(Q/ND^3)_m=(Q/ND^3)_p$
P_m=	**188.17**	**kW**	using	$(P/\rho N^3D^3)_m=(P/\rho N^3D^3)_p$