

Maximizing the amount of annual energy obtained on real PAT curves and real data from the installation (pressures and flow)

**AQUATEC**  
Dirección de Energía



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1. Aquatec experience
2. PAT curves
3. Method and Excell



*water is energy power  
and we know how  
use it*

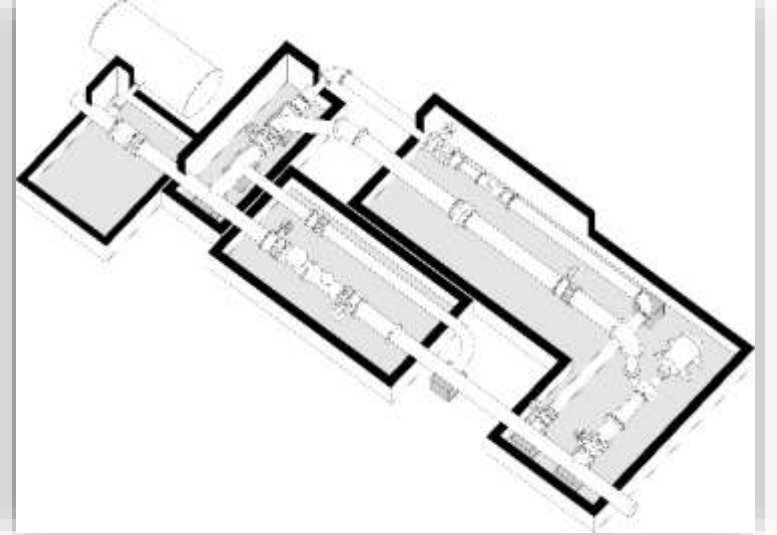


# 1. Aquatec experience

- Aquatec designs and builds mini-hydraulic installations since 2015
- Almost all facilities are designed with Pat
- Our aim is to maximize the annual energy generated at each facility
- We have developed a method that we have tested in our facilities and it is the basis of our designs.
- Some examples:
  - San Antonio (Chile) 90kw
  - Conejeras (Granada) 100kw
  - Cartuja (Granada) 90kw
  - Lerez (Pontevedra) 200kw
  - C2bis (Murcia) 50kw
  - La Trocha (Sevilla) 2x250kw

# 1. Aquatec experience

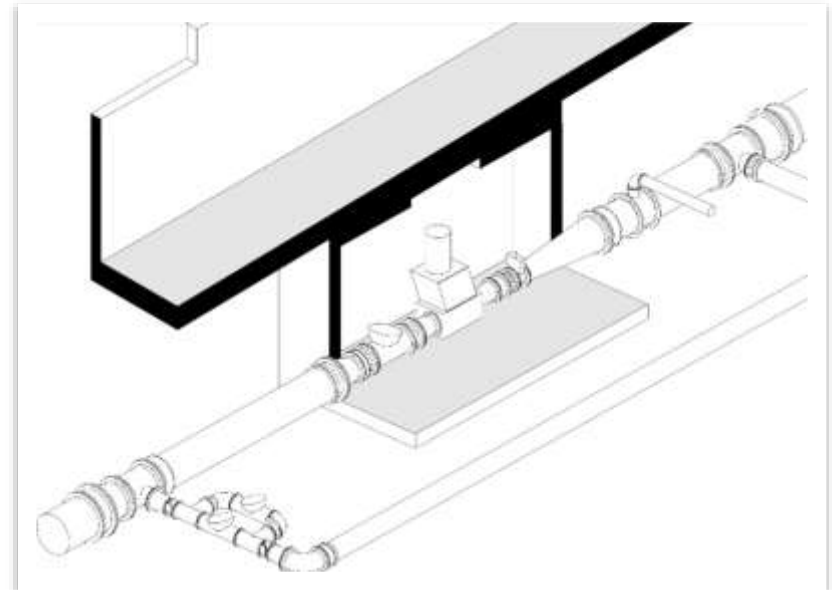
**San Antonio (Chile). 90 kW**



**Annual energy production:  
615.000 kWh/y**

# 1. Aquatec experience

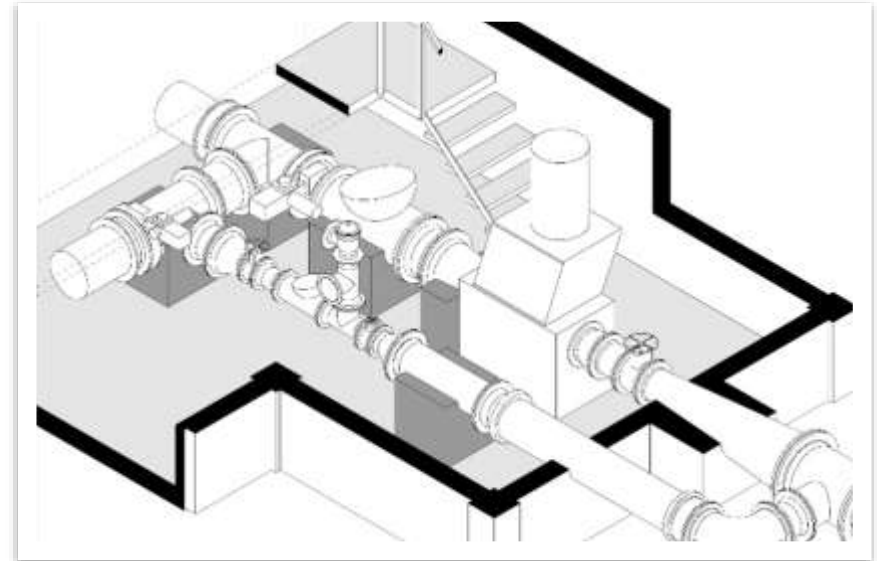
## Conejeras (Granada) 100 kW



**Annual energy production:  
900.000 kWh/y**

# 1. Aquatec experience

## Cartuja (Granada) 90 kW



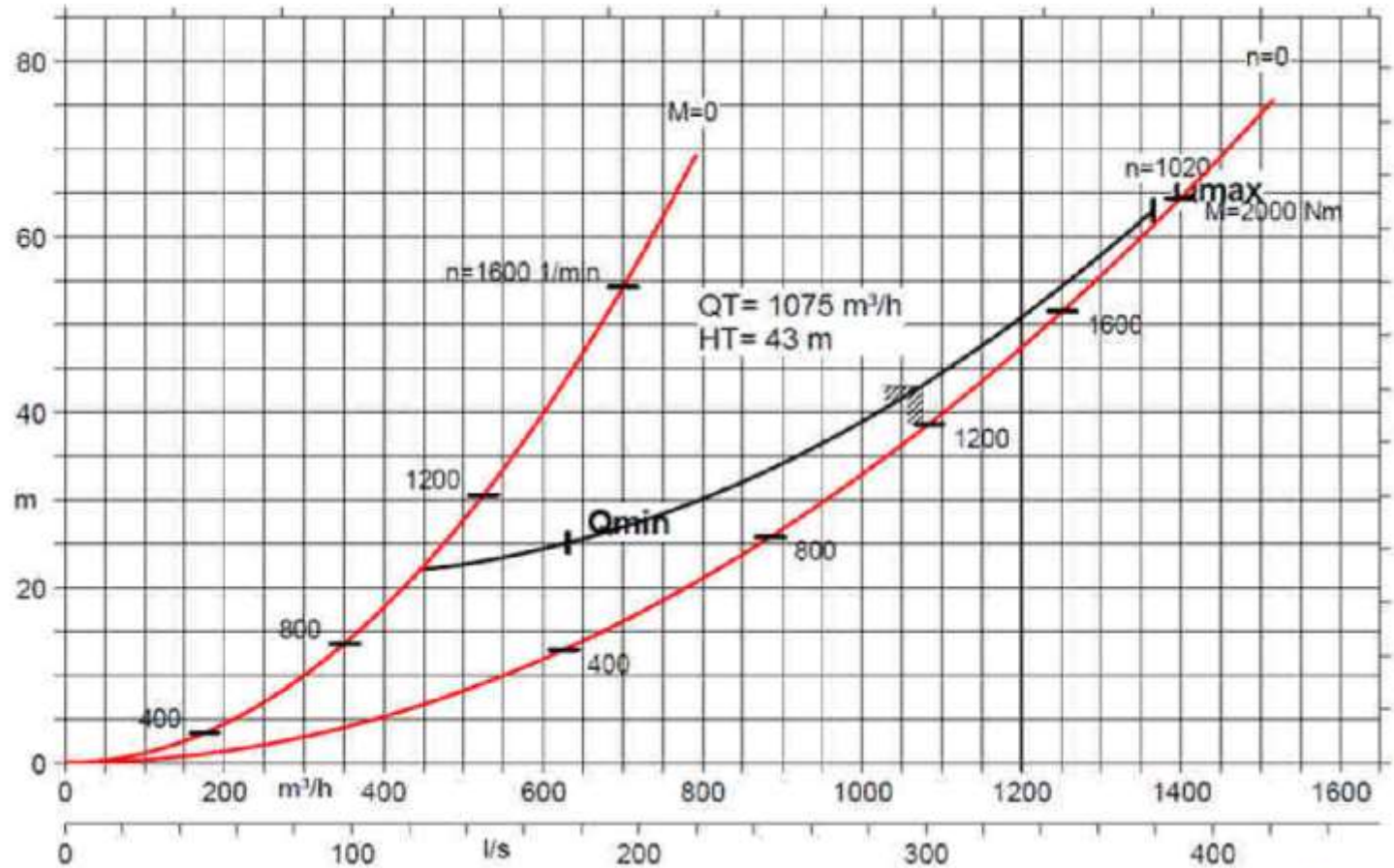
**Annual energy production:**  
**450.000 kWh/y**



## 2. PAT curves

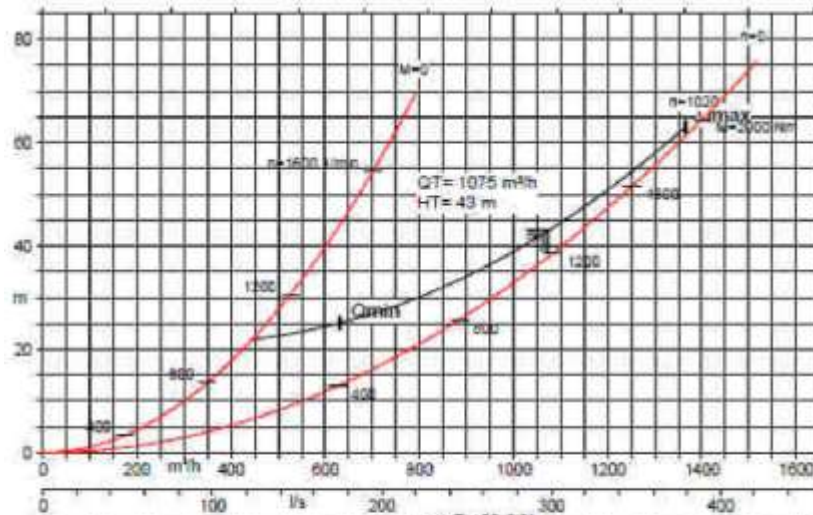
Head loss/Flow at 1020 rpm (black)

$M=0$  and  $N=0$  (red)

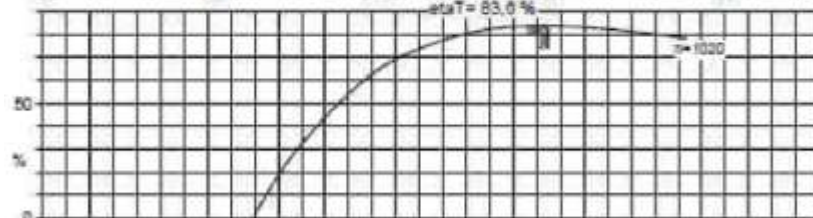


## 2. PAT curves

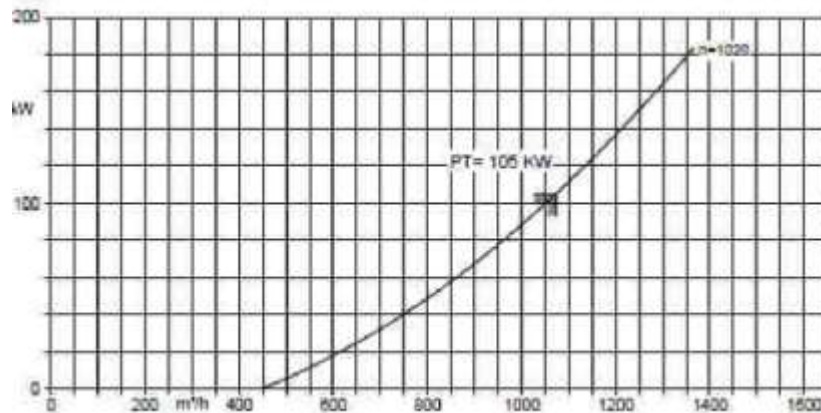
Head loss/Flow



Performance

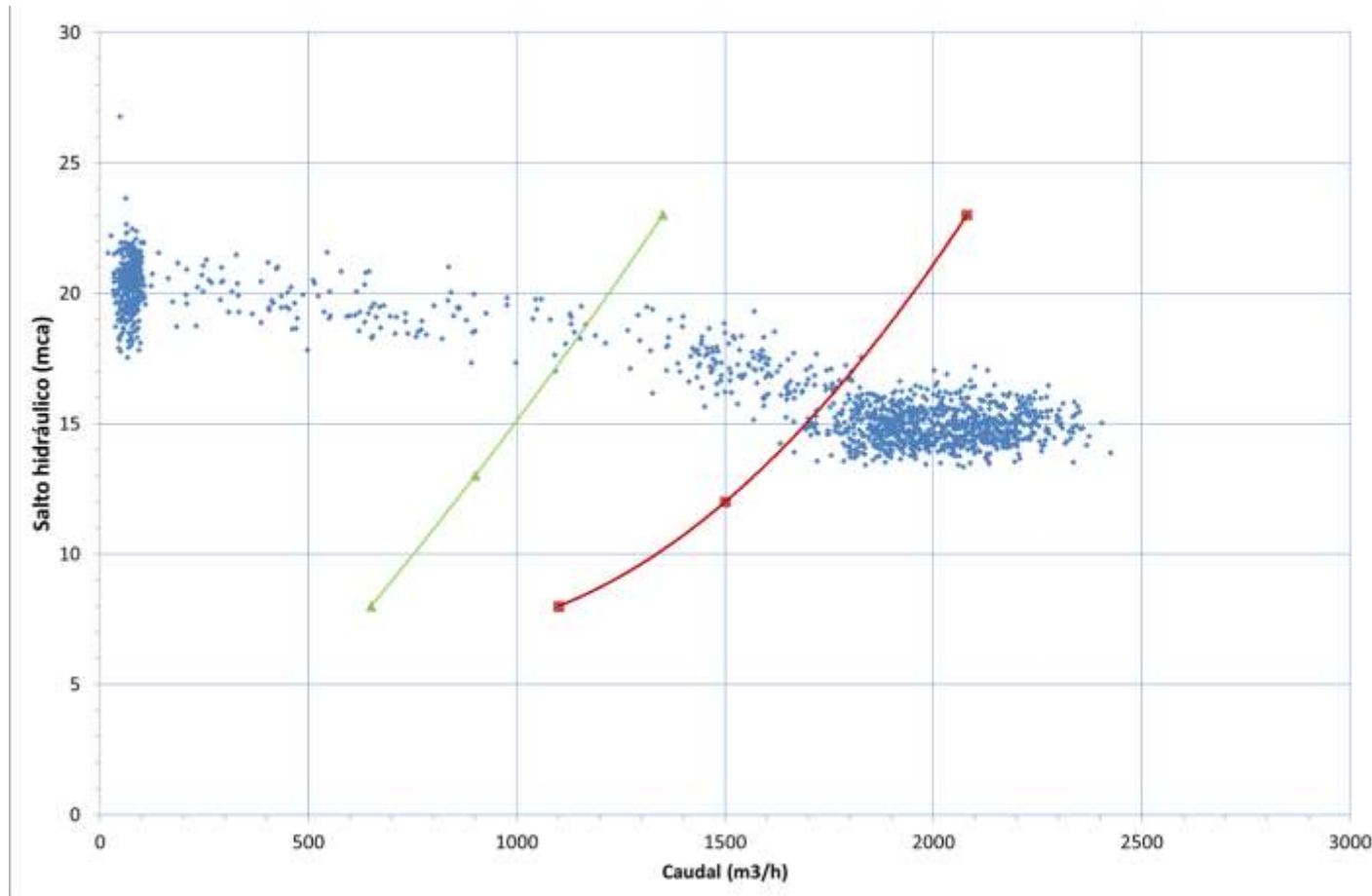


Power





## 2. PAT curves



**PAT 1: 315 Mwh/y**

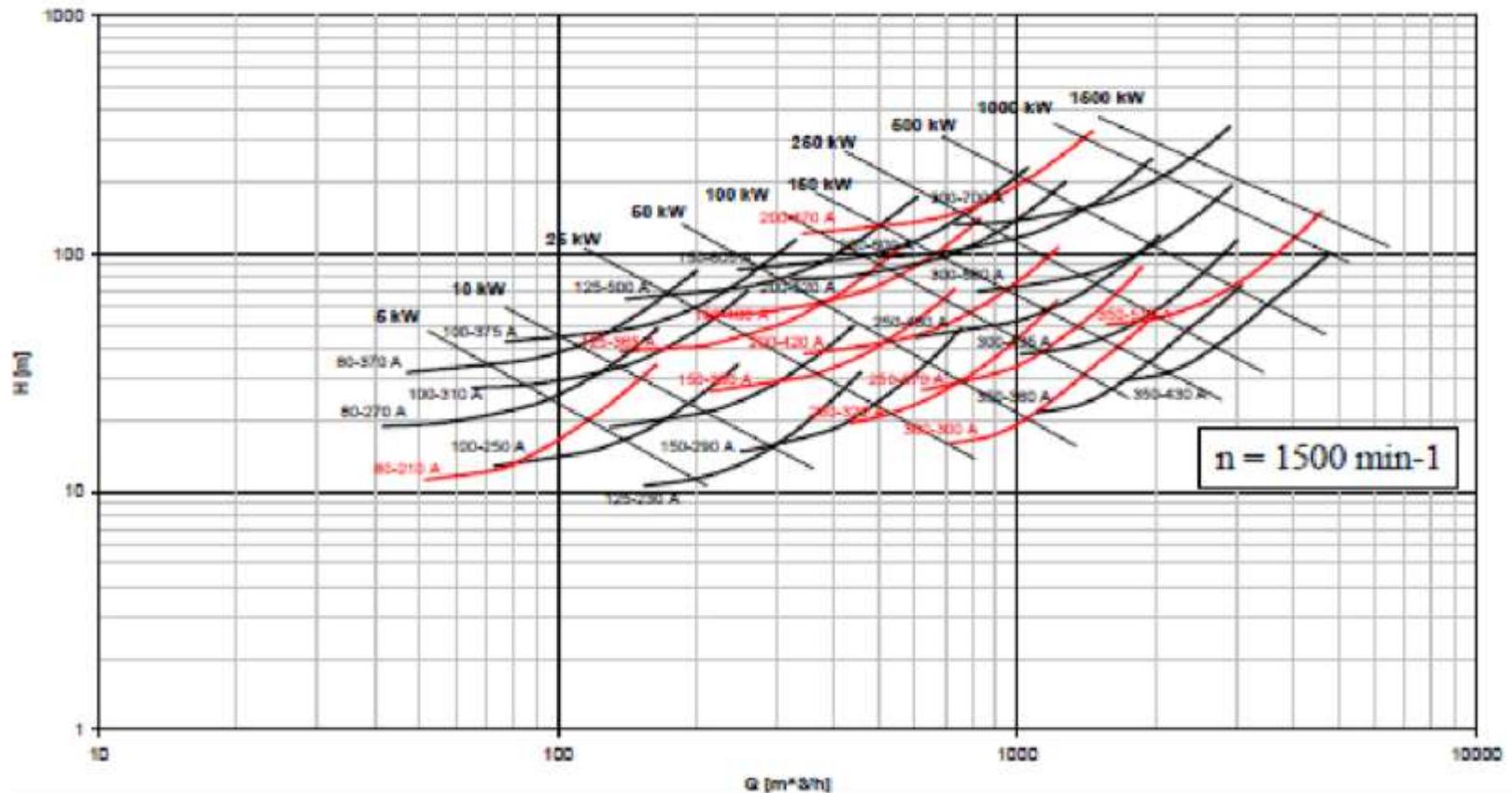
**PAT 2: 205 Mwh/y**

### 3. Method and excell

- Data collection
  - PAT curves
  - Network Head loss and Flow available
- Data Treatment
  - Excell Rank Sheet
  - Excell Selection and Results Sheet
- Calculation algorithm

### 3. Method and excell

- Data collection
  - KSR PAT H/F curves at 1 500 rpm



### 3. Method and excell

- Data collection
  - Quadratic formula and similarity laws

					1	2	3	4	5	6	7	8	9	10	11	12	
MARCA	TIPO	MODELO	RODETE	MODELO Y RODETE	REND. MAX	RPM	Q1	Q2	Q3	H1	H2	H3	P1	P2	P3		
SB	OMEGA	80-210		KSB OMEGA 80-210		75	980	34	65	105	5	7		15	0	1	3
SB	OMEGA	80-270		KSB OMEGA 80-270		75	980	27	65	105	8	11		21	0	2	5
SB	OMEGA	80-370		KSB OMEGA 80-370		75	980	30	65	131	14	16		36	0	2	11
SB	OMEGA	100-250		KSB OMEGA 100-250		75	980	48	98	163	6	7		15	0	2	6
SB	OMEGA	100-310		KSB OMEGA 100-310		75	980	42	106	173	12	16		32	0	4	11
SB	OMEGA	100-375		KSB OMEGA 100-375		75	980	50	131	216	18	26		55	0	7	20
SB	OMEGA	125-230		KSB OMEGA 125-230		80	980	105	196	294	5	7		14	0	3	8
SB	OMEGA	125-290		KSB OMEGA 125-290		80	980	91	196	287	8	12		21	0	6	13
SB	OMEGA	125-365		KSB OMEGA 125-365		80	980	97	214	370	17	24		47	0	11	37
SB	OMEGA	125-500		KSB OMEGA 125-500		80	980	98	196	392	28	33		73	0	14	56
SB	OMEGA	150-290		KSB OMEGA 150-290		83	980	163	327	490	7	10		21	0	7	22
SB	OMEGA	150-360		KSB OMEGA 150-360		83	980	144	327	483	12	17		30	0	13	28
SB	OMEGA	150-460		KSB OMEGA 150-460		83	980	144	359	545	23	34		64	0	28	61
SB	OMEGA	150-605		KSB OMEGA 150-605		83	980	163	327	719	36	43		98	0	27	137
SB	OMEGA	200-320		KSB OMEGA 200-320		83	980	287	523	810	9	14		28	0	15	42
SB	OMEGA	200-420		KSB OMEGA 200-420	415	83	980	229	523	817	16	25		47	0	28	70
SB	OMEGA	200-520		KSB OMEGA 200-520		83	980	209	392	882	33	38		85	0	29	141
SB	OMEGA	200-620		KSB OMEGA 200-620		83	980	222	457	980	55	68		141	0	56	349
SB	OMEGA	250-370		KSB OMEGA 250-370		84	980	405	915	1.241	12	21		38	0	47	100
SB	OMEGA	250-480		KSB OMEGA 250-480		84	980	408	653	1.339	19	23		53	0	35	167
SB	OMEGA	250-600		KSB OMEGA 250-600		84	980	327	653	1.274	41	53		107	0	70	321
SB	OMEGA	300-300		KSB OMEGA 300-300	330	85	980	487	925	1.315	7	13		24	0	28	66
SB	OMEGA	300-435		KSB OMEGA 300-435		85	980	653	1.307	1.960	16	25		51	0	70	195
SB	OMEGA	300-560		KSB OMEGA 300-560		85	980	536	980	1.960	30	35		85	0	70	363
SB	OMEGA	300-700		KSB OMEGA 300-700		85	980	477	915	1.927	60	68		149	0	139	614
SB	OMEGA	350-360		KSB OMEGA 350-360		86	980	784	1.307	2.025	9	16		32	0	47	167
SB	OMEGA	350-430		KSB OMEGA 350-430		86	980	1.176	1.960	3.136	13	20		43	0	89	265
SB	OMEGA	350-510		KSB OMEGA 350-510		86	980	1.045	1.960	3.005	21	36		68	0	162	418

### 3. Method and excell

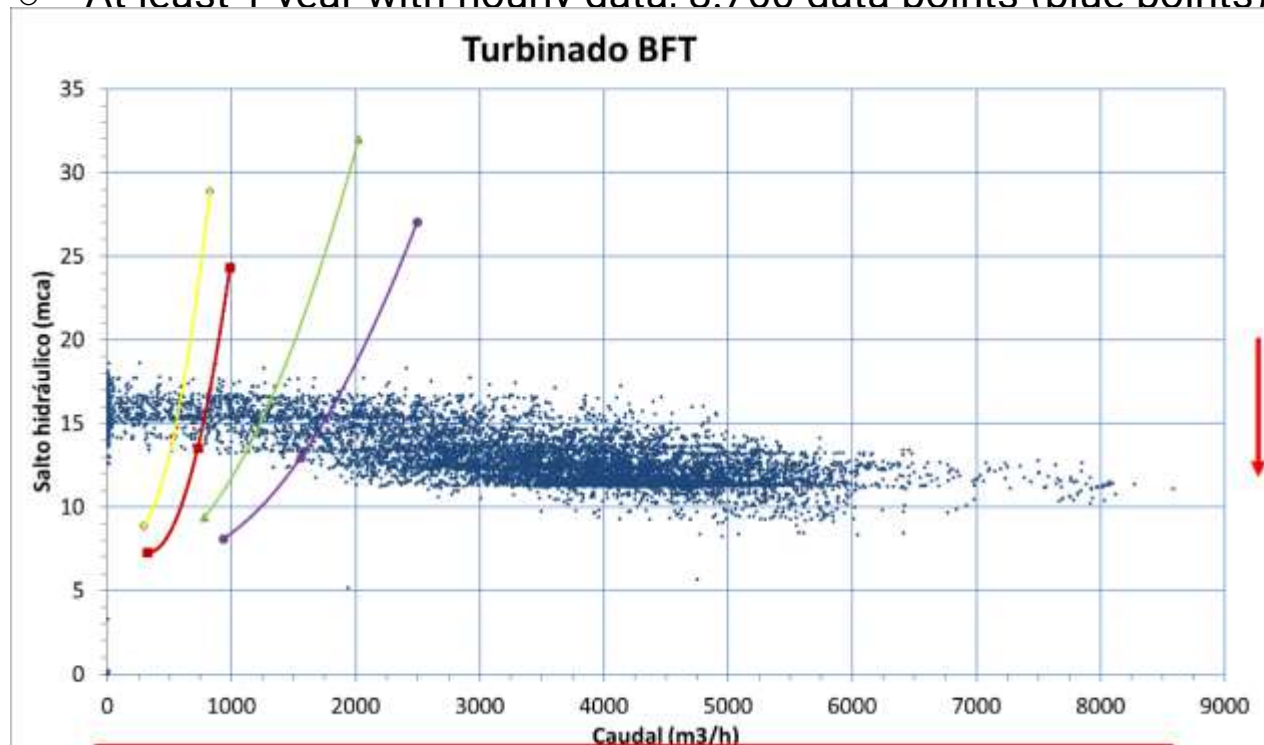
- Data collection
  - Quadratic formula and similarity laws

31	32	33	34	35	36	37	38	39	40
A	B	C	D	E	F	aux 1	aux 2	aux 3	aux 4
0,001813272	-0,1120144	6,8347808	0,00065535	-0,0472954	1,12925826	0,060526164	98,72626355	-36,951512	98,72626355
0,002225794	-0,1276437	9,93666924	0,000630041	-0,0216541	0,39866756	0,047570492	77,66899574	-20,321483	77,66899574
0,002330447	-0,149701	16,0531699	0,000807632	-0,0217056	0,20174269	-0,001858147	#iNUM!	#iNUM!	#iNUM!
0,000740333	-0,0824071	8,22208759	0,0003195	-0,0216036	0,58246619	0,022271766	156,4460184	-45,135242	156,4460184
0,001429286	-0,1513541	15,8015498	0,000483902	-0,0189604	0,21137978	0,009462489	86,97678546	18,9181165	86,97678546
0,001580176	-0,1953675	24,159107	0,000392528	0,01183432	-1,2765024	-0,029522236	#iNUM!	#iNUM!	#iNUM!
0,000269294	-0,0622651	8,68828199	0,000124444	-0,0069108	-0,3585493	0,009005884	291,8084186	-60,592158	291,8084186
0,000291667	-0,0430111	9,604	0,000130278	0,01323726	-2,0218199	0,006336663	210,195893	-62,729226	210,195893
0,000339825	-0,0475045	18,4778759	0,000264275	0,01064098	-3,2613607	-0,004578052	#iNUM!	#iNUM!	#iNUM!
0,000488889	-0,0871111	31,5864889	0,000251654	0,06544948	-8,5520656	-0,027879056	#iNUM!	#iNUM!	#iNUM!
0,000152	-0,0561867	11,9516444	0,000162027	-0,038416	2,23097363	0,004067789	394,6246345	-24,975512	394,6246345
0,000151099	-0,0407436	14,2594188	9,04915E-05	0,02450838	-5,1132863	0,001170679	248,0454221	21,6030627	248,0454221
0,000267132	-0,0848902	30,1592426	0,000119911	0,0677301	-11,933475	-0,010648209	#iNUM!	#iNUM!	#iNUM!
0,000184314	-0,0511137	39,7132723	0,000208298	0,06184223	-15,378954	-0,016750298	#iNUM!	#iNUM!	#iNUM!
0,0001	-0,0204	10,1020	0,0001	0,0204	-10,0394	0,00111	516,46	-124,46	516,46
0,0001	-0,0303	19,0236	0,0001	0,0321	-11,3614	-0,00084	#iNUM!	#iNUM!	#iNUM!
0,000100786	-0,0325791	35,6998248	0,000108919	0,0900257	-23,303231	-0,007908584	#iNUM!	#iNUM!	#iNUM!
0,000111351	-0,0212146	54,7078429	0,00042789	-0,0547865	-8,664656	-0,017926392	#iNUM!	#iNUM!	#iNUM!
3,94631E-05	-0,0328159	18,3423403	8,33681E-05	-0,0175406	-6,2949477	0,000304573	636,8966459	194,660714	636,8966459
0,0000	-0,0213	22,3603	0,0001	0,0819	-42,4675	-0,00073	#iNUM!	#iNUM!	#iNUM!
4,93648E-05	-0,0091775	38,2804323	0,000202474	0,01414397	-25,947721	-0,00481882	#iNUM!	#iNUM!	#iNUM!
1,5463E-05	-0,0072264	6,68351961	4,495E-05	-0,0011218	-9,8242	0,000470726	935,2207954	-467,88483	935,2207954
0,000021	-0,0280933	25,6106667	0,00006566	-0,0224093	-13,10697	-0,000232282	#iNUM!	#iNUM!	#iNUM!
2,70103E-05	-0,0284501	37,3685841	0,000100045	0,00465889	-30,930981	-0,001774804	#iNUM!	#iNUM!	#iNUM!
4,17702E-05	-0,038625	68,6784707	0,000103591	0,17374628	-106,14989	-0,007735777	#iNUM!	#iNUM!	#iNUM!
7,17703E-06	-0,0019381	6,49865561	6,17775E-05	-0,0389853	-7,1285745	0,000203309	1128,375149	-858,3307	1128,375149
4,62963E-06	-0,0047185	11,9516444	1,83296E-05	0,05598776	-90,912175	5,00071E-05	1273,329521	-254,12952	1273,329521
7,29167E-06	-0,0055806	19,208	3,51556E-05	0,0708765	-112,22594	-0,000136806	#iNUM!	#iNUM!	#iNUM!



### 3. Method and excell

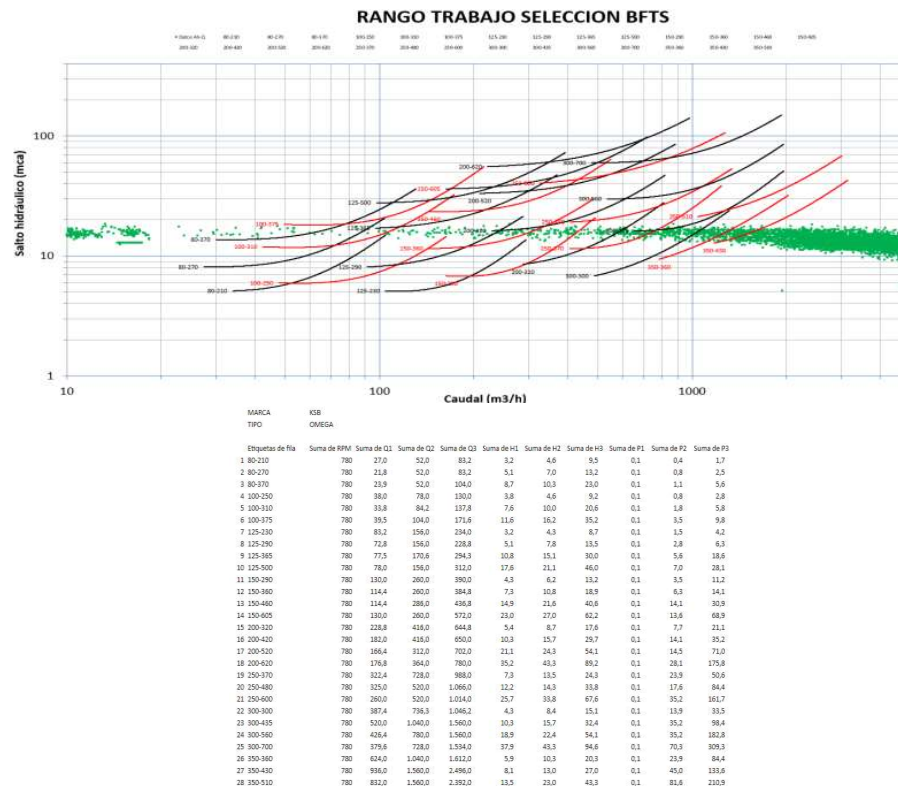
- Data collection
  - Flow and pressure drop at network (PRV, tank, PSV...)
  - Pressure drop = upstream less downstream (pressure, tank level)
  - At least 1 year with hourly data. 8.760 data points (blue points)



### 3. Method and excell

- Data treatment
  - Excel Rank Sheet (selection box, graph and dynamic table)

ROTATION SPEED	780 RPM
	3020
	1520
	1020
	780
	580



### 3. Method and excell

- Data treatment
  - Excel Rank Sheet: selection box
  - Change rotation speed apply similarity laws in graph

ROTATION SPEED	780 RPM
	3020
	1520
	1020
	780
	580

### 3. Method and excell

- Data treatment
  - Excel Rank Sheet: graph
  - All PATs H/F curves (black and red) and all network data (green)
  - Logarithmic scale



### 3. Method and excel

- Data treatment

- Excel Rank Sheet: dynamic table

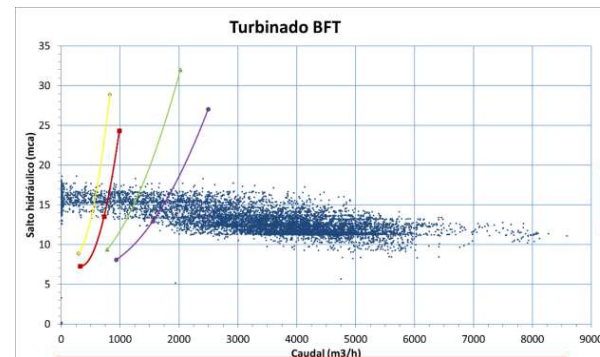
MARCA		KSB								
TIPO		OMEGA								
Etiquetas de fila	Suma de RPM	Suma de Q1	Suma de Q2	Suma de Q3	Suma de H1	Suma de H2	Suma de H3	Suma de P1	Suma de P2	Suma de P3
1 80-210	780	27,0	52,0	83,2	3,2	4,6	9,5	0,1	0,4	1,7
2 80-270	780	21,8	52,0	83,2	5,1	7,0	13,2	0,1	0,8	2,5
3 80-370	780	23,9	52,0	104,0	8,7	10,3	23,0	0,1	1,1	5,6
4 100-250	780	38,0	78,0	130,0	3,8	4,6	9,2	0,1	0,8	2,8
5 100-310	780	33,8	84,2	137,8	7,6	10,0	20,6	0,1	1,8	5,8
6 100-375	780	39,5	104,0	171,6	11,6	16,2	35,2	0,1	3,5	9,8
7 125-230	780	83,2	156,0	234,0	3,2	4,3	8,7	0,1	1,5	4,2
8 125-290	780	72,8	156,0	228,8	5,1	7,8	13,5	0,1	2,8	6,3
9 125-365	780	77,5	170,6	294,3	10,8	15,1	30,0	0,1	5,6	18,6
10 125-500	780	78,0	156,0	312,0	17,6	21,1	46,0	0,1	7,0	28,1
11 150-290	780	130,0	260,0	390,0	4,3	6,2	13,2	0,1	3,5	11,2
12 150-360	780	114,4	260,0	384,8	7,3	10,8	18,9	0,1	6,3	14,1
13 150-460	780	114,4	286,0	436,8	14,9	21,6	40,6	0,1	14,1	30,9
14 150-605	780	130,0	260,0	572,0	23,0	27,0	62,2	0,1	13,6	68,9
15 200-320	780	228,8	416,0	644,8	5,4	8,7	17,6	0,1	7,7	21,1
16 200-420	780	182,0	416,0	650,0	10,3	15,7	29,7	0,1	14,1	35,2
17 200-520	780	166,4	312,0	702,0	21,1	24,3	54,1	0,1	14,5	71,0
18 200-620	780	176,8	364,0	780,0	35,2	43,3	89,2	0,1	28,1	175,8
19 250-370	780	322,4	728,0	988,0	7,3	13,5	24,3	0,1	23,9	50,6
20 250-480	780	325,0	520,0	1.066,0	12,2	14,3	33,8	0,1	17,6	84,4
21 250-600	780	260,0	520,0	1.014,0	25,7	33,8	67,6	0,1	35,2	161,7
22 300-300	780	387,4	736,3	1.046,2	4,3	8,4	15,1	0,1	13,9	33,5
23 300-435	780	520,0	1.040,0	1.560,0	10,3	15,7	32,4	0,1	35,2	98,4
24 300-560	780	426,4	780,0	1.560,0	18,9	22,4	54,1	0,1	35,2	182,8
25 300-700	780	379,6	728,0	1.534,0	37,9	43,3	94,6	0,1	70,3	309,3
26 350-360	780	624,0	1.040,0	1.612,0	5,9	10,3	20,3	0,1	23,9	84,4
27 350-430	780	936,0	1.560,0	2.496,0	8,1	13,0	27,0	0,1	45,0	133,6
28 350-510	780	832,0	1.560,0	2.392,0	13,5	23,0	43,3	0,1	81,6	210,9



### 3. Method and excell

- Data treatment
  - Excel selection and results sheet (energy calculation and analysis)
  - Graph, data and results table and selection boxes (PAT and rotation speed)

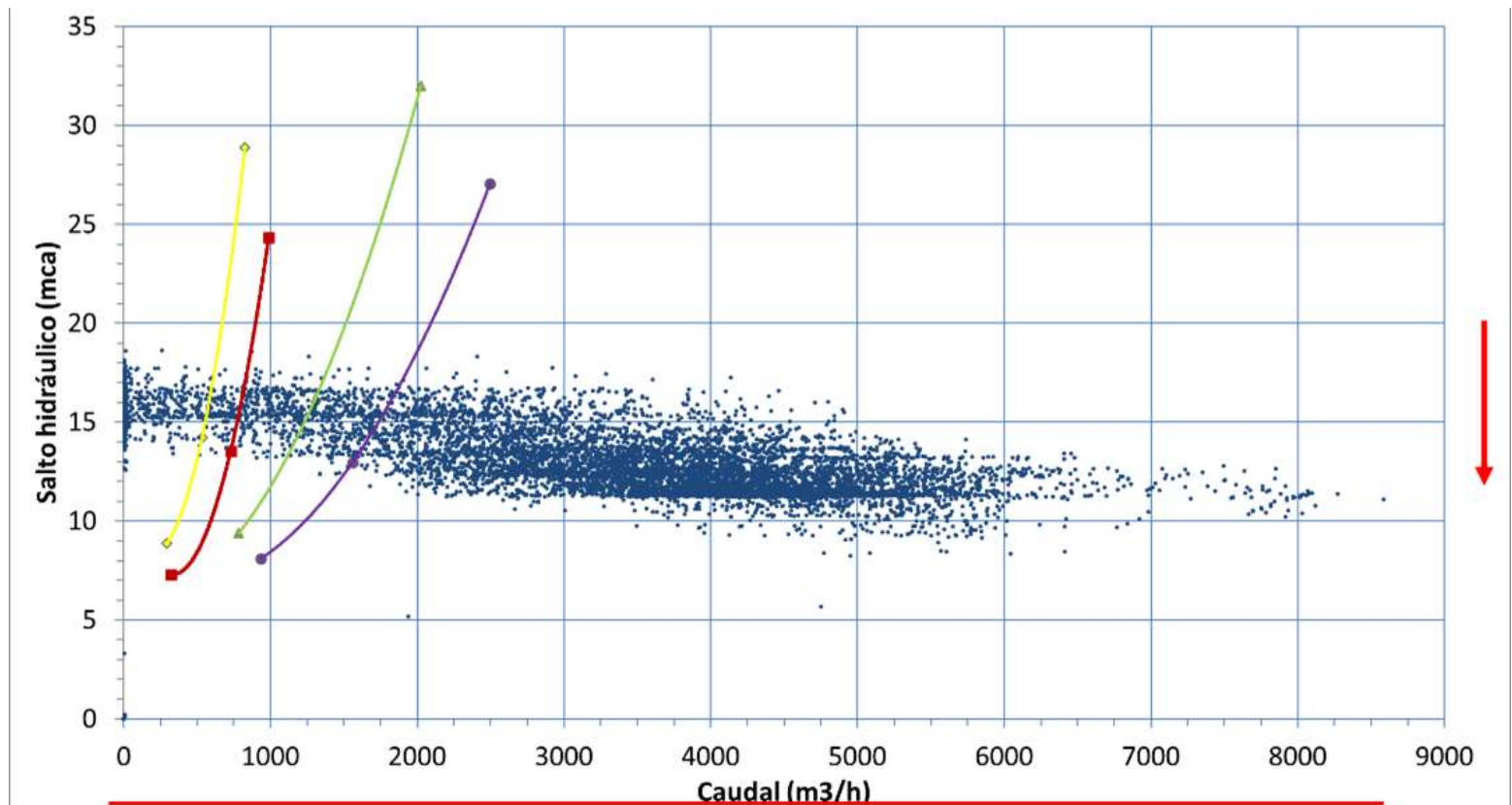
FECHA		DATOS UBICACIÓN ORIGEN		PERDIDA DE CARGA	DATOS UBICACIÓN		POT. TOTAL (MW/año)
dd/mm/aaaa	l/s	P1 mca	P2 mca	Ah (mca)	q (m³/h)	h (mca)	
01/01/2018	00:00	720,3	46,4	32,7	2593	13,7	96,79
02/01/2018	01:00	758,0	46,9	33,1	2729	13,9	103,04
03/01/2018	02:00	756,8	47,4	33,9	2724	13,5	100,38
04/01/2018	03:00	242,1	48,1	33,2	871	15,0	35,46
05/01/2018	04:00	83,0	48,6	33,1	299	15,6	12,67
06/01/2018	05:00	236,1	49,0	33,2	850	15,8	36,47
07/01/2018	06:00	1187,3	48,7	34,0	4274	14,6	170,15
08/01/2018	07:00	1229,8	48,6	34,2	4427	14,4	173,50
09/01/2018	08:00	1318,7	48,0	34,1	4747	14,0	180,41
10/01/2018	09:00	1566,6	47,8	34,8	5640	13,0	199,74
11/01/2018	10:00	1614,0	47,5	35,5	5810	12,0	189,58
12/01/2018	11:00	1583,9	47,3	35,8	5702	11,6	179,62
13/01/2018	12:00	1394,5	47,0	35,8	5020	11,2	153,34
14/01/2018	13:00	1121,6	46,4	35,1	4038	11,3	124,60
15/01/2018	14:00	1003,5	46,5	35,1	3612	11,3	111,50
16/01/2018	15:00	1000,1	46,8	35,1	3600	11,7	114,69
17/01/2018	16:00	992,2	46,9	35,4	3572	11,5	112,16
18/01/2018	17:00	1007,4	46,8	35,0	3626	11,9	117,25
19/01/2018	18:00	1034,1	46,7	34,2	3723	12,5	126,84
20/01/2018	19:00	1044,3	46,7	34,0	3760	12,7	129,94
21/01/2018	20:00	1120,9	46,4	33,9	4035	12,6	138,20
22/01/2018	21:00	1137,1	46,4	34,1	4093	12,4	137,63
23/01/2018	22:00	1012,2	46,7	33,9	3644	12,8	127,00
24/01/2018	23:00	963,5	47,1	33,4	3469	13,7	129,70
25/01/2018	00:00	967,9	47,6	33,7	3485	13,9	131,64
26/01/2018	01:00	1028,7	47,8	33,3	3703	14,5	145,78
27/01/2018	02:00	1046,6	48,1	33,7	3768	14,4	147,53



BFT 1	RPM	780	BFT 2	RPM	1020
KSB OMEGA 250-370			KSB OMEGA 350-360		
BFT 3	RPM	780	BFT 4	RPM	1020
KSB OMEGA 350-430			KSB OMEGA 200-320		

### 3. Method and excell

- Data treatment
  - Excel selection sheet (energy calculation and analysis)
  - Graph: 4 selected PATs curves and network head/flow available (blue points)



### 3. Method and excell

- Data treatment
  - Excel selection sheet (energy calculation and analysis)
  - Selection boxes (PAT and rotation speed)

BFT 1	RPM	780	BFT 2	RPM	1020
KSB OMEGA 250-370			KSB OMEGA 350-360		

BFT 3	RPM	780	BFT 4	RPM	1020
KSB OMEGA 350-430			KSB OMEGA 200-320		

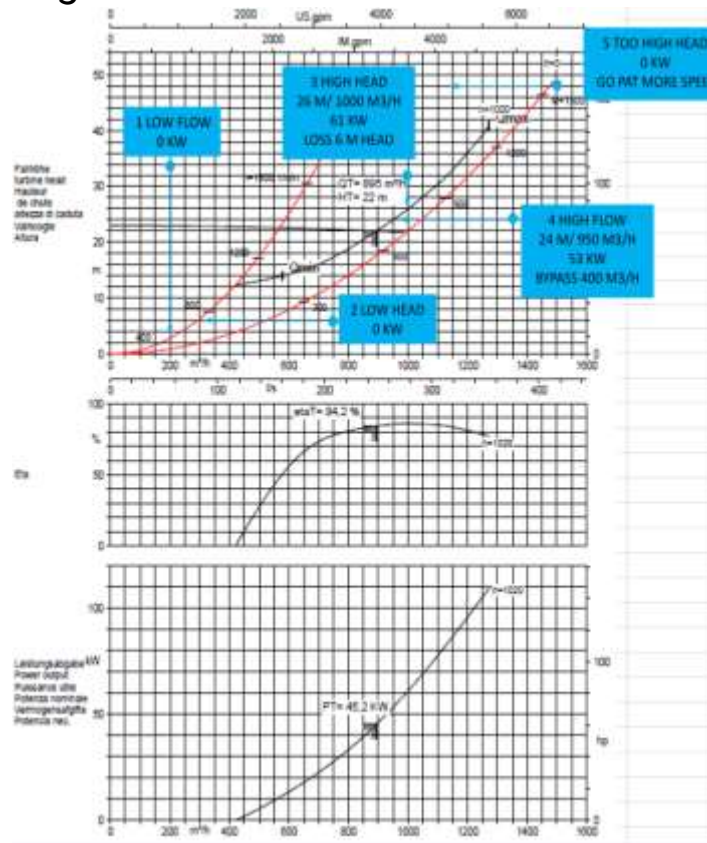
### 3. Method and excell

- Data treatment
  - Excel selection sheet (energy calculation and analysis)
  - Data and results table

						0,00		
						0,00		
						Qmed	H med	
						3229,63	13,45	
FECHA			DATOS UBICACIÓN ORIGEN		PERDIDA DE CARGA	DATOS UBICACIÓN		POT. TOTAL (MW/año)
dd/mm/aaaa		l/s	P1 mca	P2 mca	Ah (mca)	q (m³/h)	h (mca)	263.288,49
01/01/2018	00:00	720,3	46,4	32,7		2593	13,7	96,79
02/01/2018	01:00	758,0	46,9	33,1		2729	13,9	103,04
03/01/2018	02:00	756,8	47,4	33,9		2724	13,5	100,38
04/01/2018	03:00	242,1	48,1	33,2		871	15,0	35,46
05/01/2018	04:00	83,0	48,6	33,1		299	15,6	12,67
06/01/2018	05:00	236,1	49,0	33,2		850	15,8	36,47
07/01/2018	06:00	1187,3	48,7	34,0		4274	14,6	170,15
08/01/2018	07:00	1229,8	48,6	34,2		4427	14,4	173,50
09/01/2018	08:00	1318,7	48,0	34,1		4747	14,0	180,41
10/01/2018	09:00	1566,6	47,8	34,8		5640	13,0	199,74
11/01/2018	10:00	1614,0	47,5	35,5		5810	12,0	189,58
12/01/2018	11:00	1583,9	47,3	35,8		5702	11,6	179,62
13/01/2018	12:00	1394,5	47,0	35,8		5020	11,2	153,34
14/01/2018	13:00	1121,6	46,4	35,1		4038	11,3	124,60
15/01/2018	14:00	1003,5	46,5	35,1		3612	11,3	111,50
16/01/2018	15:00	1000,1	46,8	35,1		3600	11,7	114,69
17/01/2018	16:00	992,2	46,9	35,4		3572	11,5	112,16
18/01/2018	17:00	1007,4	46,8	35,0		3626	11,9	117,25
19/01/2018	18:00	1034,1	46,7	34,2		3723	12,5	126,84
20/01/2018	19:00	1044,3	46,7	34,0		3760	12,7	129,94
21/01/2018	20:00	1120,9	46,4	33,9		4035	12,6	138,20
22/01/2018	21:00	1137,1	46,4	34,1		4093	12,4	137,63
23/01/2018	22:00	1012,2	46,7	33,9		3644	12,8	127,10
24/01/2018	23:00	963,5	47,1	33,4		3469	13,7	129,70
25/01/2018	00:00	967,9	47,6	33,7		3485	13,9	131,64
26/01/2018	01:00	1028,7	47,8	33,3		3703	14,5	145,78
27/01/2018	02:00	1046,6	48,1	33,7		3768	14,4	147,53

### 3. Method and excell

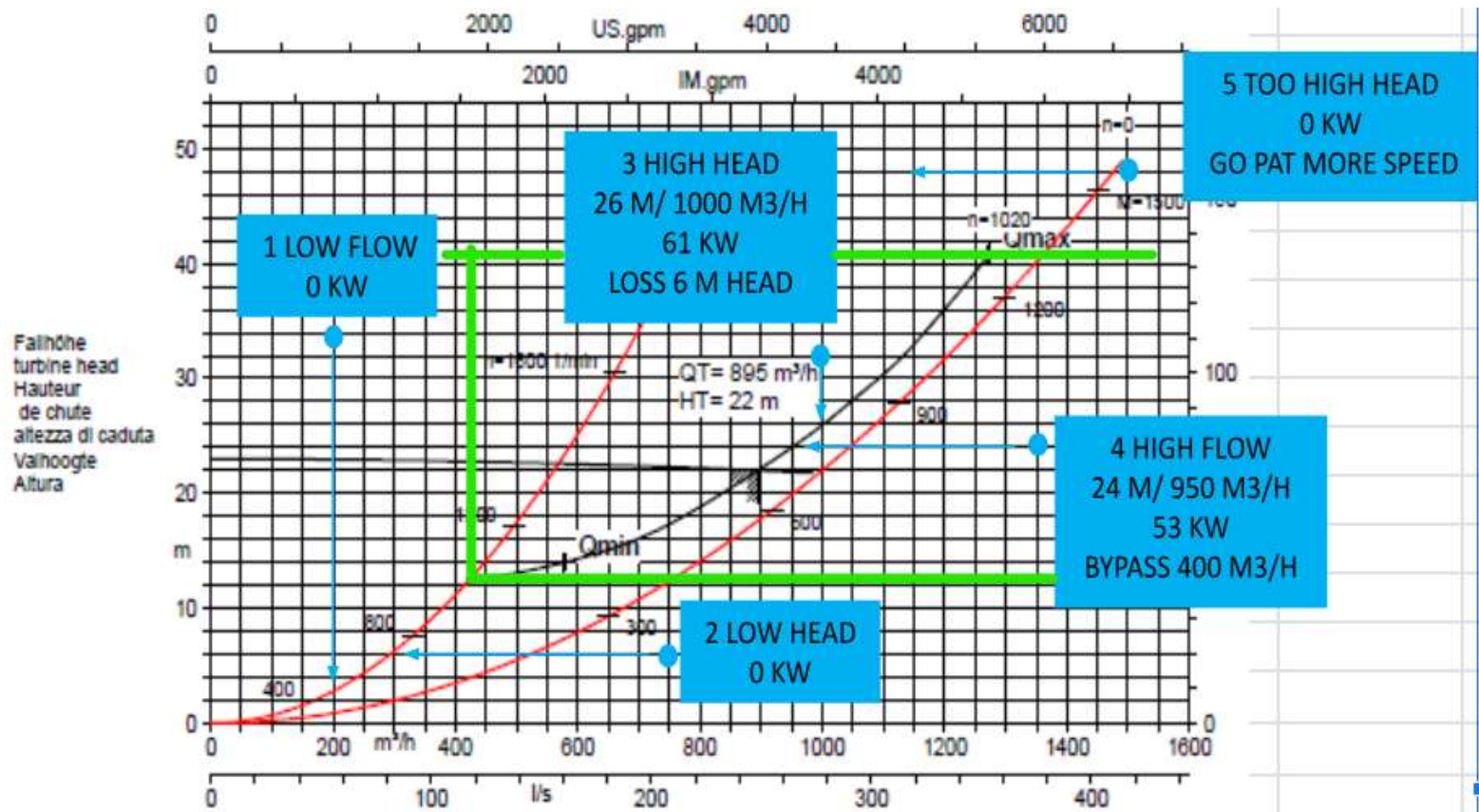
- Calculation algorithm





### 3. Method and excell

- Calculation algorithm





Agbar