Data from some of the 200 underground power houses in Norway for hydropower production

Power station	Power plant	Year	Head m	Rock	DIMENSIONS Depth[*)] m	span m	length m	height m	Roof support	Remarks
Alta	Alta	1988	100	mica schist	100	16	100	40	e	
Aurland I	Aurland	1970/87	800	granitic gneiss		15	120	35	a/e	
Blåfalli III	Blåfalli	1968	*302	granite						
Bogna	Bogna	1971	*280	granitic gneiss	300					
Borgund	Lærdal	1974	800	gneiss	1200	13.7	43.1	30	a[1)]	
Brattset	Orkla	1982	*250	phyllite						
Brokke	Brokke	1964	300	gneiss	400	12.5	90.5	31	b	
Byrte	Tokke	1968	*303	granitic gneiss						
Dividalen	Dividalen	1973	*278	mica schist						
Dokka	Dokka Etna	1989	*150	gneiss	250	11.2	52	27	e	
Driva	Driva	1973	*450	banded gneiss						
Eikelandsosen	Eikelandsosen	1987	*506	gneiss	380	11.5	28	27	e	
Fjone	Fjone	1970	*250	granitic gneiss						
Finndøla	Finndøla	1972	*295	granitic gneiss						
Grytten	Grytten	1975	*310	gneiss						
Hekni	Hekni	1994	39	gneiss						
Hjartdøla	Hjartdøla	1958	590	quartzite	200	12	61	23		
Holen	Øvre Otra	1981	*320	gneiss	700	15	60		d	
Horga	Horga	1990	*207	gneiss	300	10	30	17	e	
Hovatn	Hovatn	1971	*475	granitic gneiss						
Hove	Vikfalli	1969	*320	gneiss						
Hunderfossen	Hunderfossen	1963	45	arkosite, quartzite	50	16	57	38		
Hylen	Ulla-Førre	1986	60	gneiss	100	18	81	36	e	
Jostedal	Jostedal	1990	1100	gneiss	900	18	72	30	e	
Jukla	Mauranger	1974	*250	granitic gneiss						
Jørundland	Jørundland	1971	*280	amphibol.gneiss						
Kobbelv	Kobbelv	1985	*600	granite	400	18	70	36	e	
Kolsvik	Åbjøra	1979	*430	gneiss						
Kvilldal	Ulla-Førre	1985	*465	gneiss	600	20	130	43	e	
Kvittingen	Kvittingen		*250	metarhyolite						
Leirdøla	Leirdøla	1978	*450	granitic gneiss	400					
Lomen	Lomen	1983	*308	arkosite, quartzite	300	11.5	38	26	e	
Lomi	Lomi	1979	*570	mica schist						
Lyse I	Lyse	1957	630	gneiss	200	12.5	106	21	b	
Mauranger	Mauranger	1974	*440	gneiss						
Mel	Mel	1989	*800	gneiss						
Meråker	Meråker	1994	*264	meta-sandstone	200	14	44	29	e	
Mesna	Mesna	1983	*359	arkosite, quarztite		11		24	e	
Mosvik	Mosvik	1984	186	gneiss	250	12	36	29	e	
Naddvik	Nyset-Steggje	1987	*980	gneiss-granite	1100	15	65	32	e	
Oksla	Oksla	1980	*450	granitic gneiss						
Osa	Osa	1981	*180	quartzite, gneiss	140					
Rendal	Rendal	1971	215	arkosite, quartzite						
Saurdal	Ulla-Førre	1985	*410	gneiss	400	20	150	40	e	
trafohall	"	"	"	"	400	13	75	13	e	

Power station	Power plant	Year	Head m	Rock	DIMENSIONS Depth*) m	span m	length m	height m	Roof support	Remarks
Savalen	Savalen	1971	*250	mica schist						
Sildvik	Sildvik	1982	*640	mica schist						
Sima	Eidfjord	1981	1152	granitic gneiss	800[2)]	20	200	42	c [3)]	
Sjona	Sjona	1973	*250	mica schist						
Sjönstå	Sjönstå	1987	*125	phyllite	300					
Skibotn	Skibotn	1979	*440	mica gneiss						
Skjomen	Skjomen	1973	*360	granite	1300 [4)]	15	50	30	c	
Skollenborg	Skollenborg	1983	*60	dark gneiss	60	14	50	32	c	
Steinsland	Steinsland	1980	*470	gneiss						
Steinsfoss II	Steinsfoss	1985	*58	gneiss	130	18.5	48	35	e	
Svartisen	Svartisen	1993	*600	mica gneiss	700[5)]	18.3	85.4	36.5	e[6)]	
workshop	"	1993	-	mica schist	300	13	200	12	e	
Svelgen				quartzite						
Søa	Søa	1967	*267	granitic gneiss						
Sørfjord	Sørfjord	1982	*515	mica schist						
Tafjord K3	Tafjord	1958	*286	banded gneiss						
Tafjord K4	Tafjord	1966	*450	banded gneiss						
Tafjord K5	Tafjord	1981	*780	gneiss						
Tevla	Meråker	1994	*153	greenstone	150	13	42	25	e	
Tjodan	Tjodan	1984	*880	gneiss	1000	13.5	40	31	e	
Tokke	Tokke	1962	390	quartzite	450	18	98	36	a	
Tonstad	Sira-Kvina	1968	448	gneiss		16		37	b	
Torpa	Dokka-Etna	1989	*450	phyllite, quartzite	200	12.7	51	29.5	e	
Trollheim	Trollheimen	1968	*297	quartzrich gneiss						
Ulset	Orkla		*280	mica gneiss						
Usta	Usta	1965		gneiss						
Ustekveikja	Ustekveikja	1982?		gneiss						
Ulvik II	Ulvik	1974	*370	phyllite or gneiss						
Vemundsbotn	Vemundsbotn	1976	*250	gneiss						
Vinstra II	Vinstra	1990	*448	phyllite	250	14.5	96	40	b/e	
Øljusjøen	Lærdal	1974	*250	phyllite	200	12	30	30	a	
Övre Rössåga	Rössåga	1962	136	limestone	130	16	72	40	a	
Åbjøra(Valdres)	Åbjøra S	1951	430	phyllite, quartzite		17	95	18		
Åbjöra (Tosen)	Åbjøra N	1980	507	gneiss						
Åmæla I	Åmæla	1977	*500	banded gneiss						
Åmæla II	Åmæla	1977	*514	banded gneiss						
Årøy	Årøy	1983	*147	gneiss	300	16	55	41	e	

Method for *roof* support

a. cast in place concrete lining b. free-spanning concrete arch c. rock bolts and unreinforced shotcrete
d. rock bolts and reinforced shotcrete e. rock bolts and fibre reinforced shotcrete

*Max head in *unlined* pressure tunnel or pressure shaft. (The minimum rock stress is here larger than the head.)

*) The depth is measured from nearby hills/peaks located closer than 30^{o} from the power house.

1) Heavy rock burst problems; successive excavation and cast in place concrete lining.

2) Principal rock stresses measured as: $\sigma1$= 19.5 MPa, $\sigma2$ = 9.5 MPa, $\sigma3$ = 3.2 MPa.

3) Heavy rock burst problems in Sima power house; rock support by 20 000 bolts (5 m long) in roof and walls and additional net reinforced shotcrete in the roof.

4) Principal rock stresses measured as: $\sigma1$ = 17.3 MPa, $\sigma2$ = 2.3 MPa, $\sigma3$ = 1.6 MPa.

5) Principal rock stresses measured as: $\sigma1$ = 18.7 MPa, $\sigma2$ = 9.5 MPa, $\sigma3$ = 6.2 MPa.

6) A detailed description of the ground condition and rock support has been given by F. Löset: Engineering geology, excavation and rock support at Svartisen power plant (in Norwegian), in proceedings from Fjellsprengningsteknikk, Bergmekanikk, Geoteknikk 1990, 13 pp.

Data on air cushion surge chambers in hydropower plants

Power plant	Year	Max. air pressure MPa	Rock	Depth m	DIMENSION Volume 1000 m^3	span m	height m
Driva	1973	4.2	banded gneiss	1100	7.35	12.5	10.3
Jukla	1974	2.4	granitic gneiss	340	6.05	12	12
Oksla	1980	4.4	granitic gneiss	625	18	17.5	14.5
Sima	1980	4.8	granitic gneiss	425	9.5	14.7	13
Osa	1981	1.9	gneissic granite	142	12.5	14	11.5
Kvilldal	1981	4.1	migmatitic gneiss	522	110	16	17 to 24
Tafjord	1982	7.7	banded gneiss	658	1.95	15	15
Brattset	1982	2.5	phyllite	150	8.9	10	10
Ulset	1985	2.8	mica gneiss	264	4.9	11	9
Torpa	1989	4.4	meta siltstone, quartzite	225	12	9	10

Data on some large hydropower tunnels with span ≥ 10 m

Hydropower plant	Type of tunnel	Year	Rock	Cross section m^2	DIMENSIONS span m	length km	height m	Remarks
Hunderfossen	tailrace	1963	arkosite, quartzite	130	12	4.0	11.5	
Langevatn	headrace	1964	mica gneiss	140		3.6		
Sarpsfoss	tailrace	1977	granite	220	15	0.4	16	
Rygene	tailrace	1977	dark gneiss	105	11	2.2	11	
Skollenborg	tailrace	1983	dark gneiss	105	11	3.1	10	
Steinsfossen II	headrace	1985		105	10	3.5	11	
Solbergfoss	tailrace	1985	gneiss	270	21	0.16	18.5	Max.dimensions
Kvilldal	headrace	1985	gneiss	100		10.5		
	tailrace	"	"	130		1.0		
Saurdal	headrace	1985	gneiss	110		13.0		
Hylen	headrace	1986	gneiss	160		2.0		
	tailrace	"	"	200		0.3		
Hogga	tailrace	1987	gneiss	143		2.56		
Hekni	headrace	1994	gneiss	115	12.5	5.4	10.6	
	tailrace	"	"	115		0.675		

The rock support installed is adapted to the rock mass conditions encountered: Occasional use of rock bolts, and shotcrete (if required), cast in place concrete lining of roof and walls in large weakness zones (faults).