

Ny utgave 2011

Vg2 elektro

Teori med
praktiske
øvinger

Kunnskaps-
løftet

Frank Fosbæk

Automatiserte anlegg

Vg2 automatisering

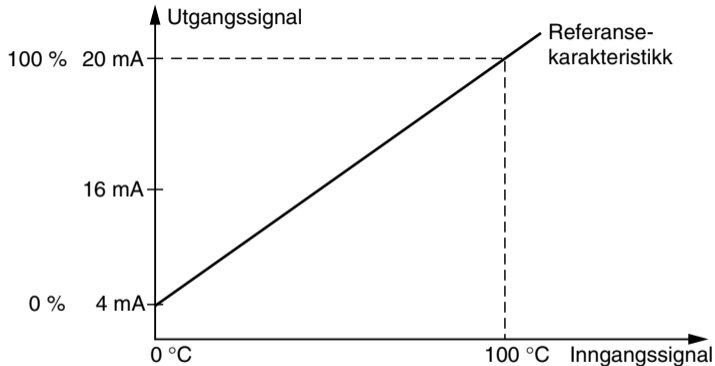
ELFORLAGET

Illustrasjoner til Automatiserte anlegg Vg2 automatisering

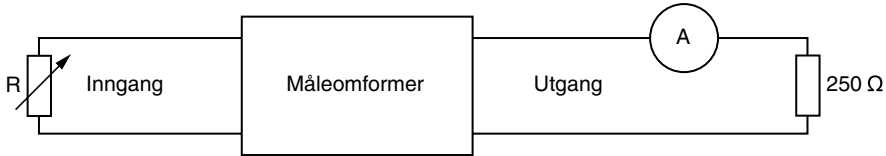
Kapittel 17

Illustrasjonene kan brukes fritt i undervisningen

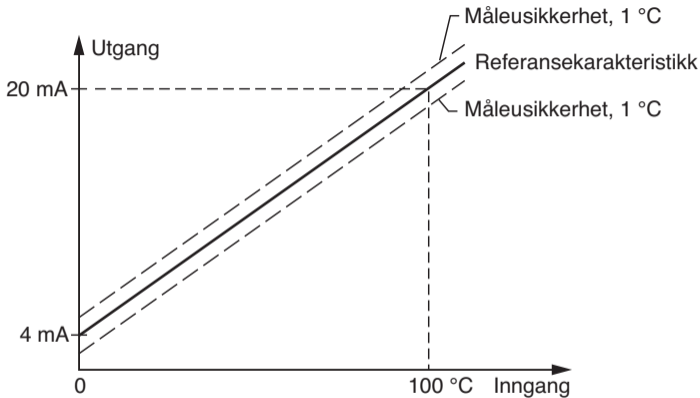
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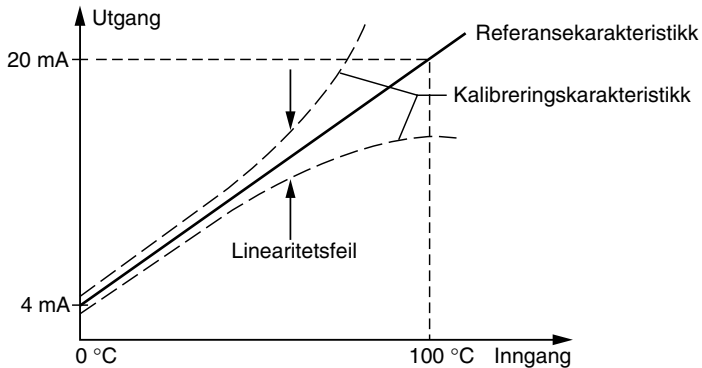
Figur 17.1 Referanse-karakteristikk



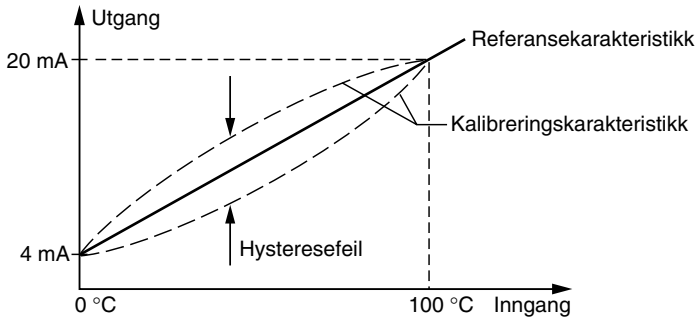
Figur 17.2 Oppkobling for kalibrering



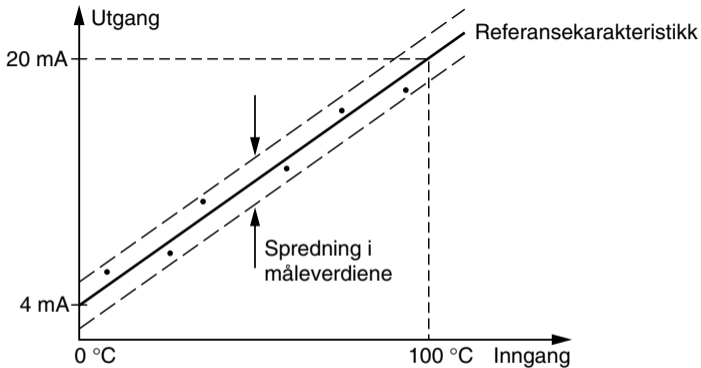
Figur 17.3 Måleusikkerhet i referansekarakteristikken



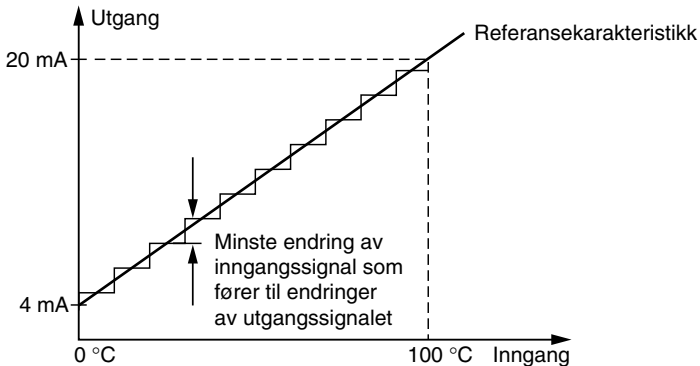
Figur 17.4 Linearitetsfeil



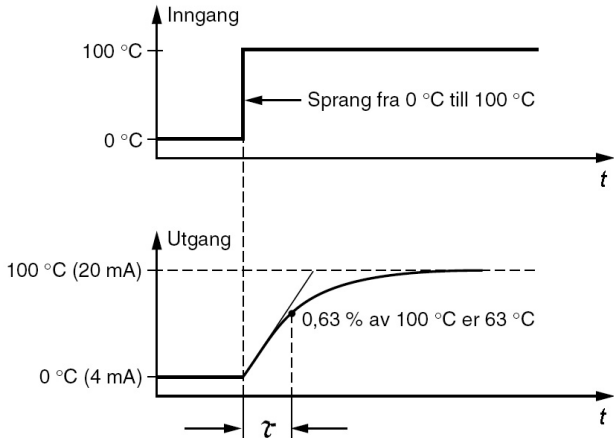
Figur 17.5 Hystereseffil



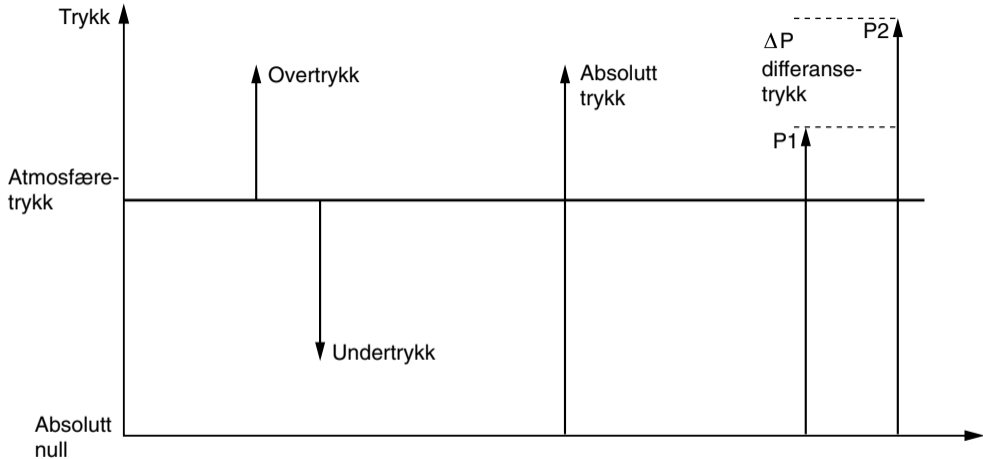
Figur 17.6 Repeterbarhet



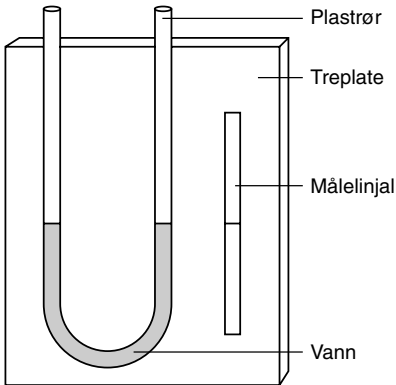
Figur 17.7 Opplosningsevne



Figur 17.8 Stigetiden for utgangssignalet



Figur 17.9 Forholdet mellom ulike typer trykk

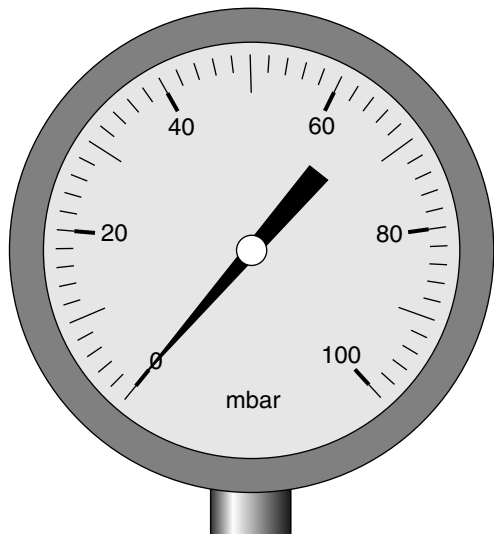


Figur 17.10 U-rørsmanometer

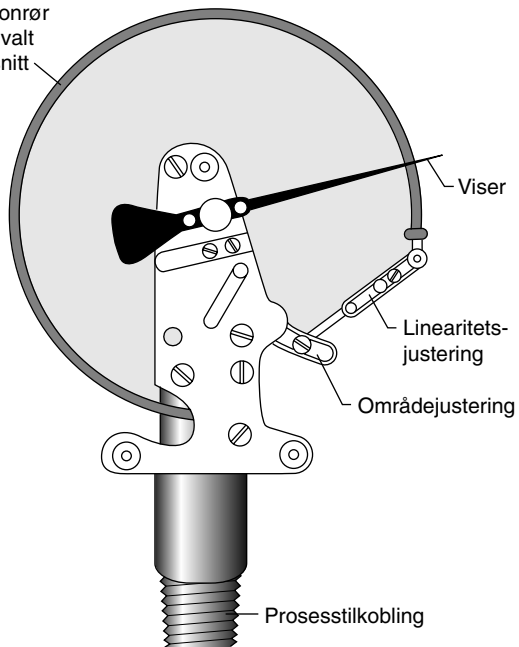
Pa (= N/m ²)	bar	kp/cm ² (= at)	Torr (mmHg)	Lbf/in ² (psi)
1	$10 \cdot 10^{-6}$	$10,1972 \cdot 10^{-6}$	$7,50062 \cdot 10^{-3}$	$0,145038 \cdot 10^{-3}$
$100 \cdot 10^3$	1	1,01972	750,062	14,5038
$98,0665 \cdot 10^3$	0,980665	1	735,559	14,2233
$9,80665 \cdot 10^6$	98,0665	100	$73,5559 \cdot 10^3$	$1,42233 \cdot 10^3$
133,332	$1,33322 \cdot 10^{-3}$	$1,335951 \cdot 10^{-3}$	1	$19,3368 \cdot 10^3$
$101,325 \cdot 10^3$	1,01325	1,03323	760	14,6959
$6,89476 \cdot 10^3$	$68,9476 \cdot 10^{-3}$	$70,3070 \cdot 10^{-3}$	51,7149	1

1 pascal = 1 N/m² 1, Torr = 1 mmHg ved 0 °C, 1 mm vann-søyle = 9,81 N/mm², 1 lbf/in² blir også kalt 1 psi

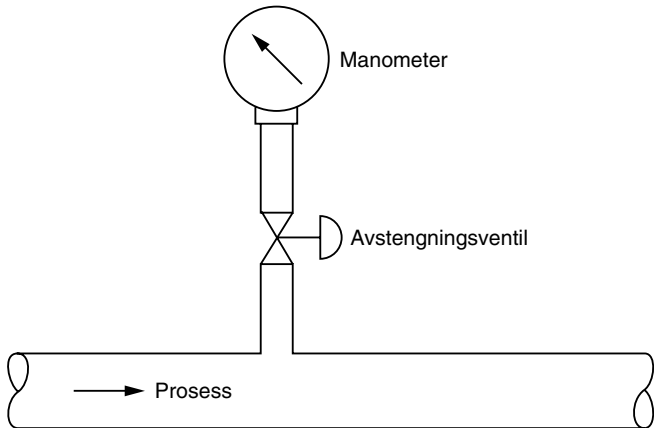
Figur 17.11 Omregningstabell for de mest brukte trykkbenevningene



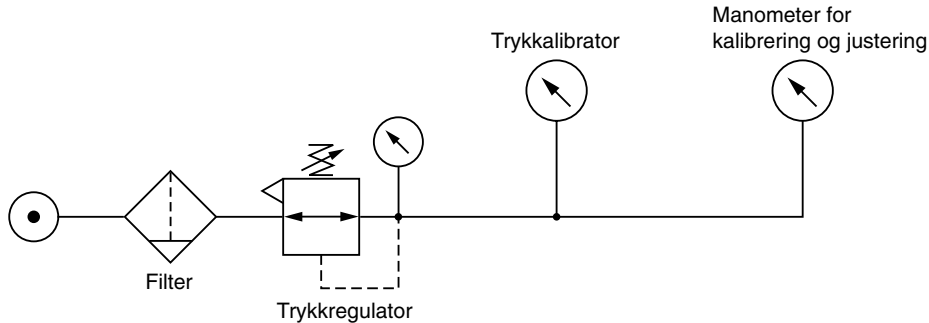
Bourdonrør
med ovalt
tværsnitt



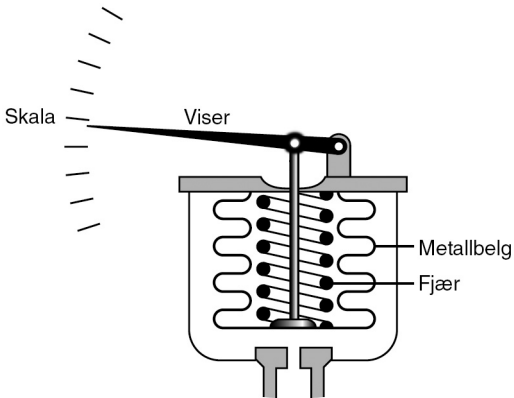
Figur 17.12 Bourdonmanometer



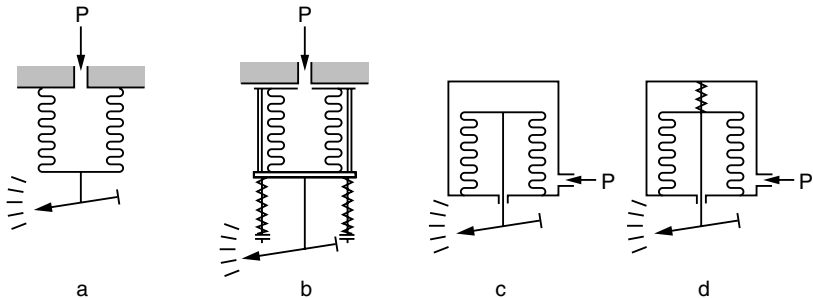
Figur 17.13 Montering av manometer



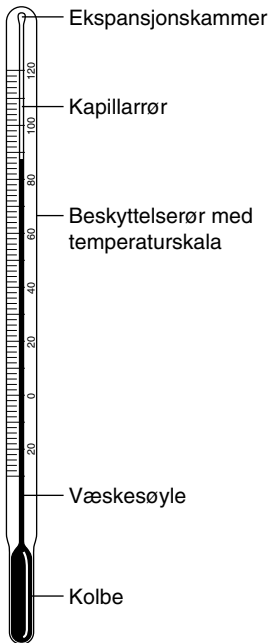
Figur 17.14 Oppkobling for kalibrering og justering



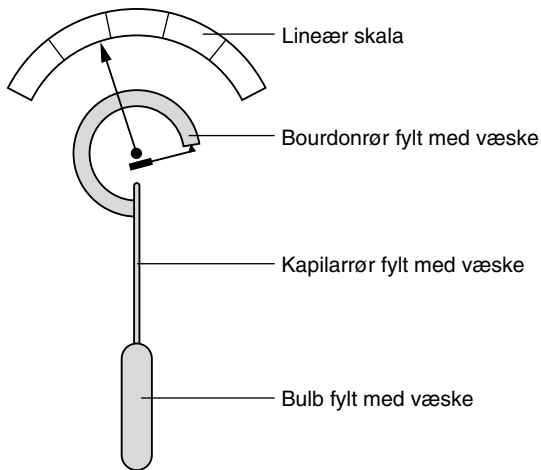
Figur 17.15 Belgmanometer



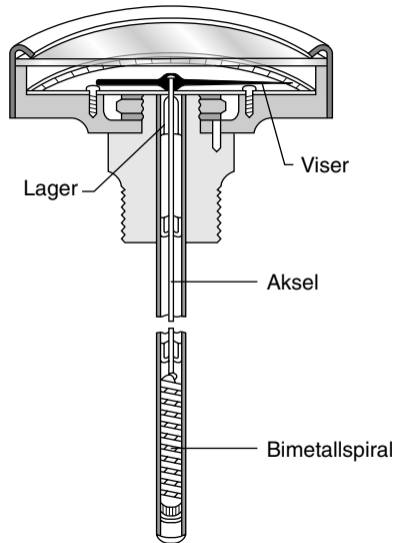
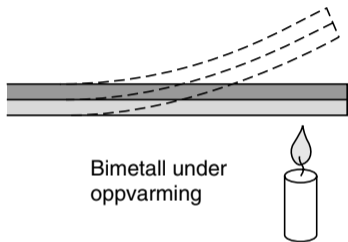
Figur 17.16 Ulike utførelser av belgmanometere



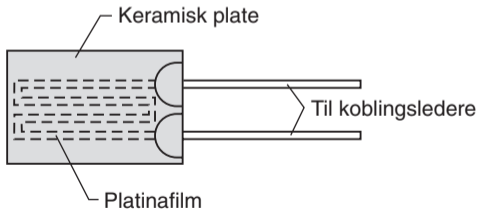
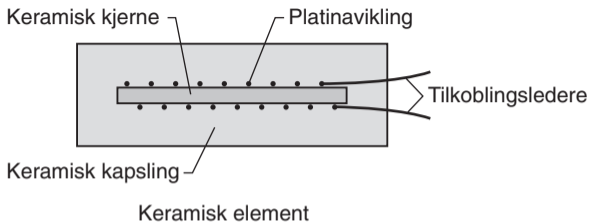
Figur 17.17 Væsketermometer



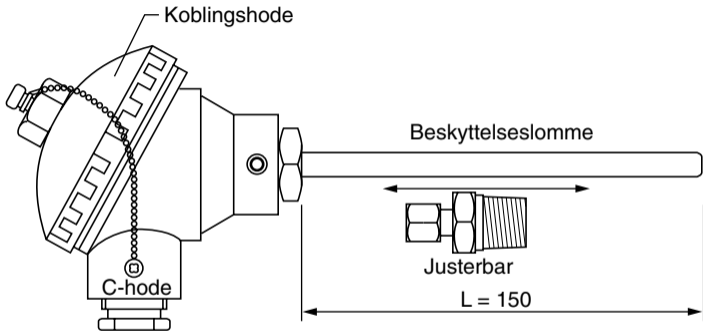
Figur 17.18 Væsketrykktermometer



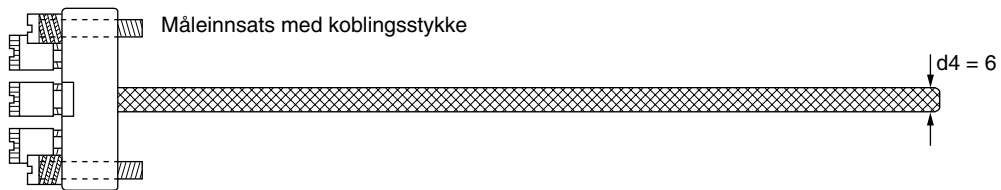
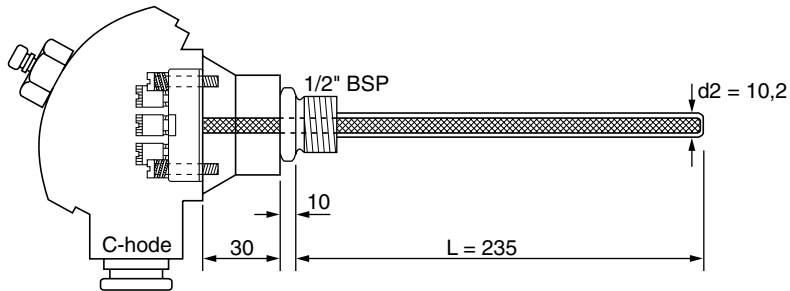
Figur 17.19 Bimetalltermometer



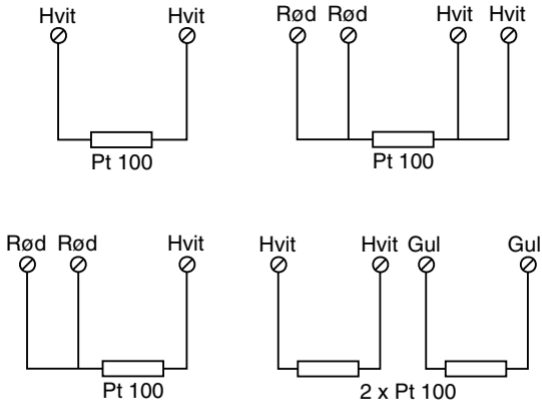
Figur 17.20 Gjennomskåret, keramisk element og filmelement



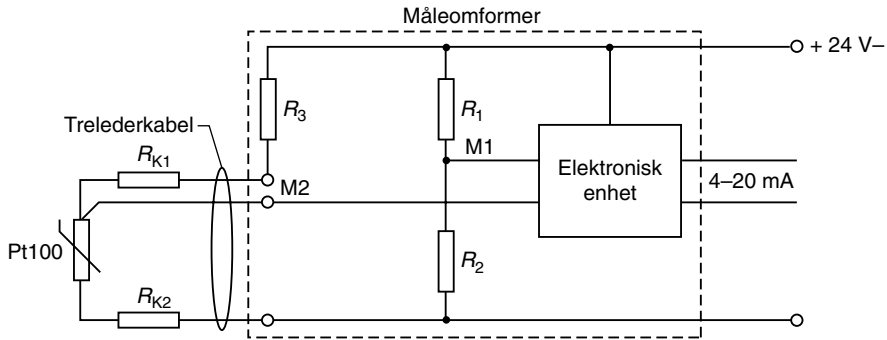
Figur 17.21 Beskyttelseslomme med fast innsats



Figur 17.22 Beskyttelseslomme med løs innsats og løs innsats med koblingsstykke



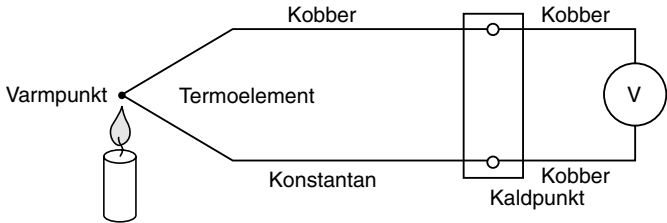
Figur 17.23 Koblingskjema for Pt100-element



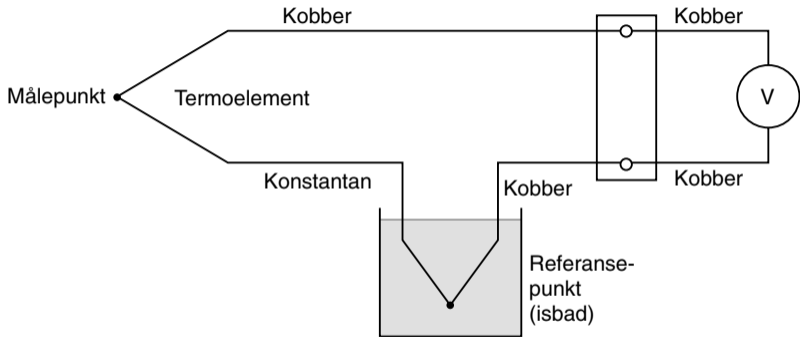
Figur 17.24 Trelederkoblet måleelementet

°C ITS 90	0	1	2	3	4	5	6	7	8	9	10
-200	18,52										
0	100,00	100,39	100,78	101,17	101,56	101,95	102,34	102,73	103,12	103,51	103,90
10	103,90	104,29	104,68	105,07	105,46	105,85	106,24	106,63	107,02	107,40	107,79
20	107,79	108,18	108,57	108,96	109,35	109,73	110,12	110,51	110,90	111,29	111,67
30	111,67	112,06	112,45	112,83	113,22	113,61	114,00	114,38	114,77	115,15	115,54
40	115,54	115,93	116,31	116,70	117,08	117,47	117,86	118,24	118,63	119,01	119,40
50	119,40	119,78	120,17	120,55	120,94	121,32	121,71	122,09	122,47	122,86	123,24
60	123,24	123,63	124,01	124,39	124,78	125,16	125,54	125,93	126,31	126,69	127,08
70	127,08	127,46	127,84	128,22	128,61	128,99	129,37	129,75	130,13	130,52	130,90
80	130,90	131,28	131,66	132,04	132,42	132,80	133,18	133,57	133,95	134,33	134,71
90	134,71	135,09	135,47	135,85	136,23	136,61	136,99	137,37	137,75	138,13	138,51
100	138,51	138,88	139,26	139,64	140,02	140,40	140,78	141,16	141,54	141,91	142,29
110	142,29	142,67	143,05	143,43	143,80	144,18	144,56	144,94	145,31	145,69	146,07
120	146,07	146,44	146,82	147,20	147,57	147,95	148,33	148,70	149,08	149,46	149,83
130	149,83	150,21	150,58	150,96	151,33	151,71	152,08	152,46	152,83	153,21	153,58
140	153,58	153,96	154,33	154,71	155,08	155,46	155,83	156,20	156,58	156,95	157,33
150	157,33	157,70	158,07	158,45	158,82	159,19	159,56	159,94	160,31	160,68	161,05
160	161,05	161,43	161,80	162,17	162,54	162,91	163,29	163,66	164,03	164,40	164,77
170	164,77	165,14	165,51	165,89	166,26	166,63	167,00	167,37	167,74	168,11	168,48
180	168,48	168,85	169,22	169,59	169,96	170,33	170,70	171,07	171,43	171,80	172,17
190	172,17	172,54	172,91	173,28	173,65	174,02	174,38	174,75	175,12	175,49	175,86
200	175,86	176,22	176,59	176,96	177,33	177,69	178,06	178,43	178,79	179,16	179,53
210	179,53	179,89	180,26	180,63	180,99	181,36	181,72	182,09	182,46	182,82	183,19
220	183,19	183,55	183,92	184,28	184,65	185,01	185,38	185,74	186,11	186,47	186,84
230	186,84	187,20	187,56	187,93	188,29	188,66	189,02	189,38	189,75	190,11	190,47
240	190,47	190,84	191,20	191,56	191,92	192,29	192,65	193,01	193,37	193,74	194,10
250	194,10	194,46	194,82	195,18	195,55	195,91	196,27	196,63	196,99	197,35	197,71
260	197,71	198,07	198,43	198,79	199,15	199,51	199,87	200,23	200,59	200,95	201,31
270	201,31	201,67	202,03	202,39	202,75	203,11	203,47	203,83	204,19	204,55	204,90
280	204,90	205,26	205,62	205,98	206,34	206,70	207,05	207,41	207,77	208,13	208,48
290	208,48	208,84	209,20	209,56	209,91	210,27	210,63	210,98	211,34	211,70	212,05
300	212,05	212,41	212,76	213,12	213,48	213,83	214,19	214,54	214,90	215,25	215,61
310	215,61	215,96	216,32	216,67	217,03	217,38	217,74	218,09	218,44	218,80	219,15
320	219,15	219,51	219,86	220,21	220,57	220,92	221,27	221,63	221,98	222,33	222,68
330	222,68	223,04	223,39	223,74	224,09	224,45	224,80	225,15	225,50	225,85	226,21
340	226,21	226,56	226,91	227,26	227,61	227,96	228,31	228,66	229,02	229,37	229,72

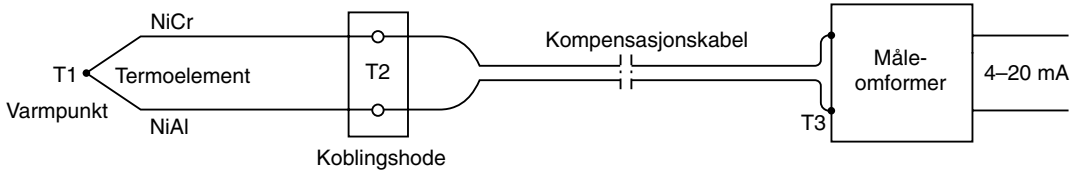
Figur 17.25 Forholdet mellom resistans og temperatur for Pt100-elementer



Figur 17.26 Voltmeter koblet til termoelement



Figur 17.27 viser målekobling med isbad som referansetemperatur



Figur 17.28 Kobling med kompensasjonskabel

Element typer:			Pol	Merknad	Ny	Gammel		
					DIN IEC 584-3	BS1843-1981	ANSI MC96-1	DIN 43710-4
J	Fe	Jern	+	Magnetisk				
	Cu-Ni	Konstantan	-					
T	Cu	Kopper	+	Brun				
	Cu-Ni	Konstantan	-					
K	Ni-Cr	Nikkel krom	+	Magnetisk				
	Ni-Al	Nikkel aluminium	-					
B	Pt-30 Rh	Platina 30% Rhodium	+	1)				
	Pt-6Rh	Platina 6% Rhodium	-					
R	Pt-13Rh	Platina 13% Rhodium	+	Myk				
	Pt	Platina	-					
S	Pt-10Rh	Platina 10% Rhodium	+	Myk				
	Pt	Platina	-					
E	Ni-Cr	Nikkel krom	+	1)				
	Cu-Ni	Konstantan	-					
N	Ni-Cr-Si	Nicrosil	+	1)				
	Ni-Si-Mg	Nisil	-					

1) Ingen spesielle kjennetegn, men ved å tvinne trådene sammen og varme opp dette målepunktet vil + og - lett verifiseres med å koble til et millivoltmeter.

Figur 17.29 Fargekoden for termoelementer og kompensjonskabel

T-element Temperatur / EMK tabell i henhold til IEC 584-1										
°C	0	10	20	30	40	50	60	70	80	90
-200	-5,603	-5,753	-5,889	-6,007	-6,105	-6,181	-6,232	-6,258		
-100	-3,378	-3,656	-3,923	-4,177	-4,419	-4,648	-4,865	-5,069	-5,261	-5,439
0	0,000	-3,383	-0,757	-1,121	1,475	-1,819	-2,152	-2,475	-2,788	-3,089
0	0,000	0,391	0,789	1,196	1,611	2,035	2,467	2,908	3,357	3,813
100	4,277	4,749	5,227	5,712	6,204	6,702	7,207	7,718	8,235	8,757
200	9,286	9,820	10,360	10,905	11,456	12,011	12,572	13,137	13,707	14,281
300	14,860	15,443	16,030	16,621	17,217	17,816	18,420	19,027	19,638	20,252
400	20,869									

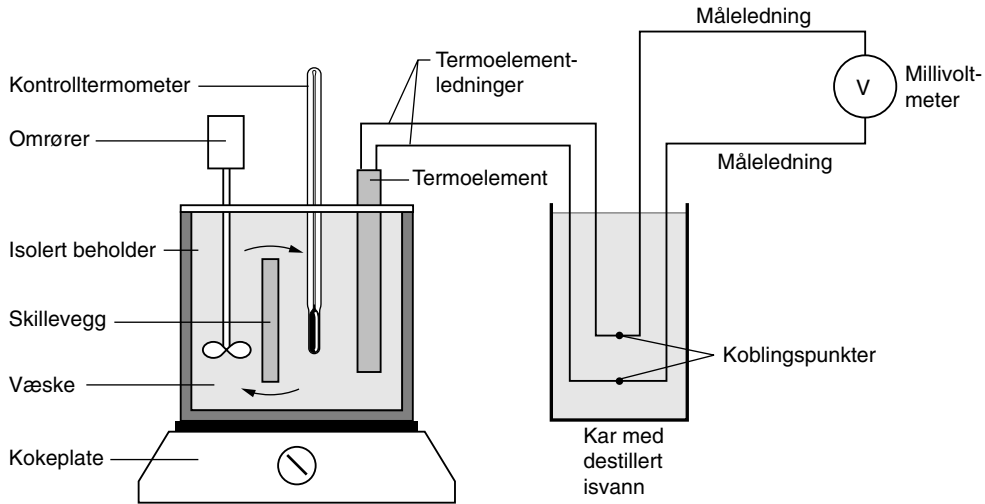
J-element Temperatur / EMK tabell i henhold til IEC 584-1										
°C	0	10	20	30	40	50	60	70	80	90
-200	-7,890	-8,096								
-100	-4,632	-5,036	-5,426	-5,801	-6,159	-6,499	-6,821	-7,122	-7,402	-7,659
0	0	-0,501	-0,995	-1,481	-1,960	-2,431	-2,892	-3,344	-3,785	-4,215
0	0	0,507	1,019	1,536	2,058	2,585	3,115	3,649	4,186	4,725
100	5,268	5,812	6,359	6,907	7,457	8,008	8,560	9,113	9,667	10,222
200	10,777	11,332	11,887	12,442	12,998	13,553	14,108	14,663	15,217	15,771
300	16,325	16,879	17,432	17,984	18,537	19,089	19,640	20,192	20,743	21,295
400	21,846	22,397	22,949	23,501	24,054	24,607	25,161	25,716	26,272	26,829
500	27,388	27,949	28,511	29,075	29,642	30,210	30,782	31,356	31,933	32,513
600	33,096	33,683	34,237	34,867	35,464	36,066	36,671	37,280	37,893	38,510
700	39,130	39,754	40,382	41,013	41,647	42,283	42,922	43,563	44,207	44,852
800	45,498	46,144	46,790	47,434	48,076	48,716	49,354	49,989	50,621	51,249
900	51,875	52,496	53,115	53,729	54,341	54,948	55,553	56,155	56,753	57,349

E-element Temperatur / EMK tabell i henhold til IEC 584-1										
°C	0	10	20	30	40	50	60	70	80	90
-200	-8,824	-9,063	-9,274	-9,455	-9,604	-9,719	-9,797	-9,835		
-100	-5,237	-5,680	-6,107	-6,516	-6,907	-7,279	-7,631	-7,963	-8,273	-8,561
0	0	-0,581	-1,151	-1,709	-2,254	-2,787	-3,306	-3,811	-4,301	-4,777
0	0	0,591	1,192	1,801	2,419	3,047	3,683	4,329	4,983	5,646
100	6,317	6,996	7,683	8,377	9,078	9,787	10,501	11,222	11,949	12,681
200	13,419	14,161	14,909	15,661	16,417	17,178	17,942	18,710	19,481	20,256
300	21,033	21,814	22,597	23,383	24,171					

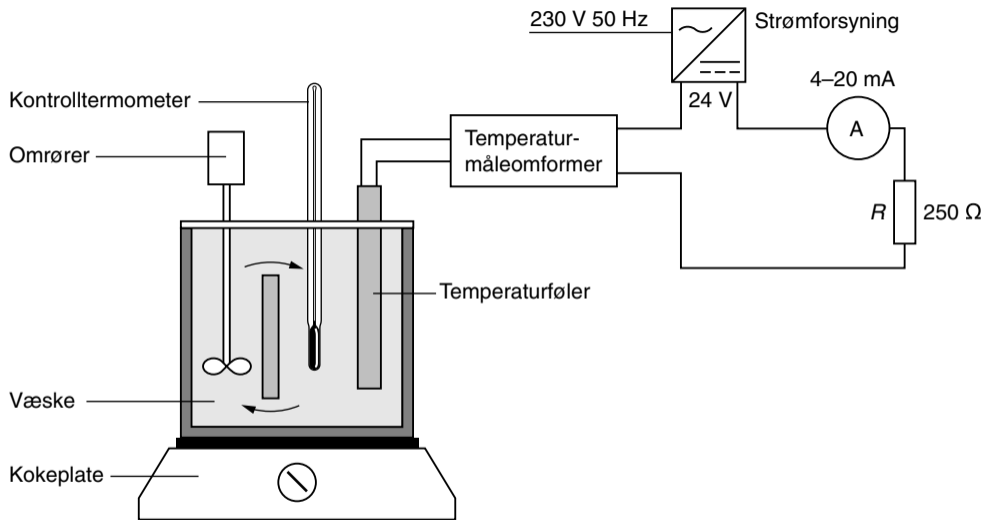
K-element Temperatur / EMK tabell i henhold til IEC 584-1										
°C	0	10	20	30	40	50	60	70	80	90
-100	-3,553	-3,852	-4,138	-4,410	-4,669	-4,912	-5,141	-5,354	-5,550	-5,730
0	0	-0,392	-0,777	-1,156	-1,527	-1,889	-2,243	-2,586	-2,920	-3,242
0	0	0,397	0,798	1,203	1,611	2,022	2,436	2,850	3,266	3,681
100	4,095	4,508	4,919	5,327	5,733	6,137	6,539	6,939	7,338	7,737
200	8,137	8,537	8,938	9,341	9,745	10,151	10,560	10,969	11,381	11,793
300	12,207	12,623	13,039	13,456	13,874	14,292	14,712	15,132	15,552	15,974
400	16,395	16,818	17,241	17,664	18,088	18,513	18,938	19,363	19,788	20,214
500	20,640	21,066	21,493	21,919	22,346	22,772	23,198	23,624	24,050	24,476
600	24,902	25,327	25,751	26,176	26,599	27,022	27,445	27,867	28,288	28,709
700	29,128	29,547	29,965	30,383	30,799	31,214	31,629	32,042	32,455	32,866
800	33,277	33,686	34,095	34,502	34,909	35,314	35,718	36,121	36,524	36,925
900	37,325	37,724	38,122	38,519	38,915	39,310	39,703	40,096	40,488	40,879
1000	41,269	41,657	42,045	42,432	42,817	43,202	43,585	43,968	44,349	44,729
1100	45,108	45,486	45,863	46,238	46,612	46,985	47,356	47,726	48,095	48,462
1200	48,828	49,192	49,555	49,916	50,276	50,633	50,990	51,344	51,697	52,049
1300	52,398	52,747	53,093	53,439	53,782	54,125	54,466	54,807		

N-element Temperatur / EMK tabell i henhold til IEC 584-1										
°C	0	10	20	30	40	50	60	70	80	90
0	0,000	0,261	0,525	0,793	1,064	1,340	1,619	1,902	2,188	2,479
100	2,774	3,072	3,374	3,679	3,988	4,301	4,617	4,936	5,258	5,584
200	5,912	6,243	6,577	6,914	7,254	7,596	7,940	8,287	8,636	8,987
300	9,340	9,695	10,053	10,412	10,773	11,135	11,499	11,865	12,233	12,602
400	12,972	13,344	13,717	14,092	14,467	14,844	15,222	15,601	15,981	16,362
500	16,744	17,127	17,511	17,896	18,282	18,668	19,055	19,443	19,831	20,220
600	20,609	20,999	21,390	21,781	22,172	22,564	22,956	23,348	23,740	24,133
700	24,526	24,919	25,312	25,705	26,098	26,491	26,885	27,278	27,671	28,063
800	28,456	28,849	29,241	29,633	30,025	30,417	30,808	31,199	31,590	31,980
900	32,370	32,760	33,149	33,538	33,927	34,315	34,702	35,089	35,476	35,862
1000	36,248	36,633	37,018	37,403	37,786	38,169	38,552	38,934	39,316	39,696
1100	40,076	40,456	40,835	41,213	41,590	41,966	42,342	42,717	43,091	43,464
1200	43,836	44,207	44,578	44,947	45,315	45,682	46,048	46,413	46,777	47,140
1300	47,502									

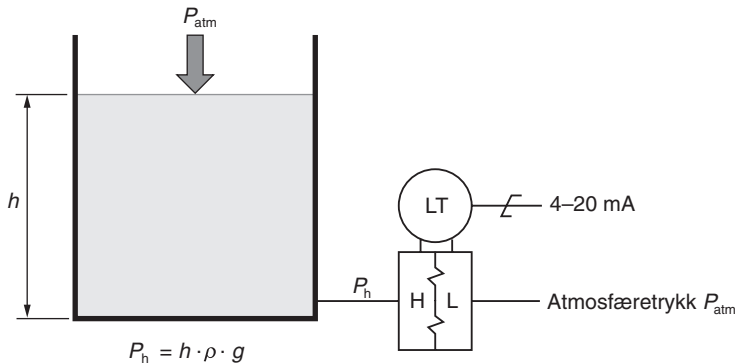
Figur 17.30 Forholdet mellom temperatur og spenning for noen termoelementer



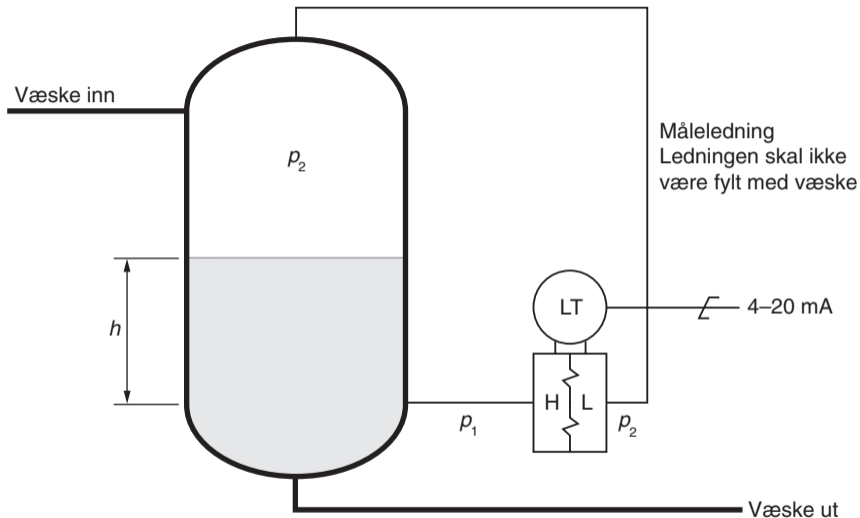
Figur 17.31 Eksempel på kalibrator med kalibreringsbad



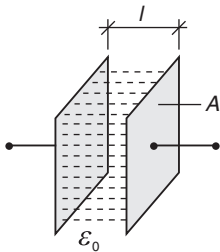
Figur 17.32 Kontroll av temperaturmåleomformer med temperaturføler



Figur 17.33 Måling av nivået med differansetrykkmåler d/p-celle



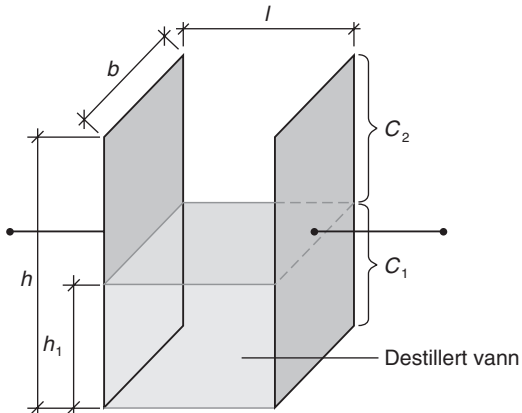
Figur 17.34 Måling av differansetrykket i lukket tank med dp-celle



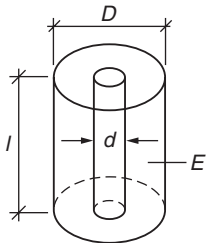
Figur 17. 35 Skisse av en platekondensator

Materiale	ϵ_r
Olje	2,5
Alkohol	3
Bensin	3
Destillert vann	80

Figur 17.36



Figur 17.37 Måling av nivået i en tank med destillert vann

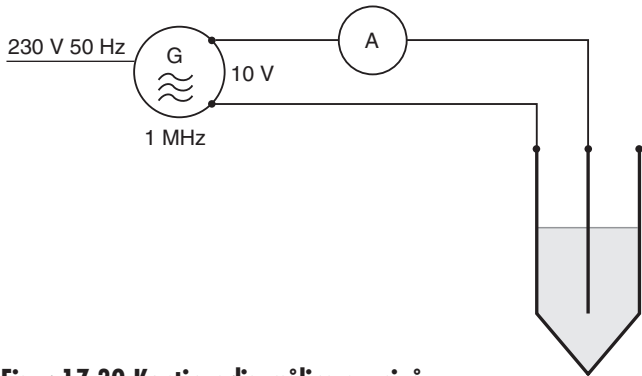


Formel for beregning av en sylindrisk kondensator:

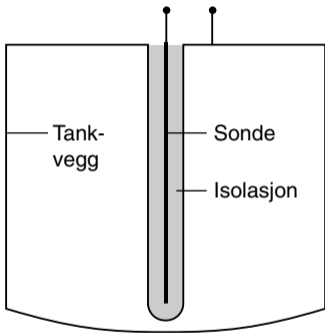
$$C = \frac{2 \cdot \pi \cdot \epsilon_0 \cdot \epsilon_r \cdot l}{\ln(D/d)}$$

$\ln(D/d)$ er den naturlige logaritmen til forholdet mellom diametrene.

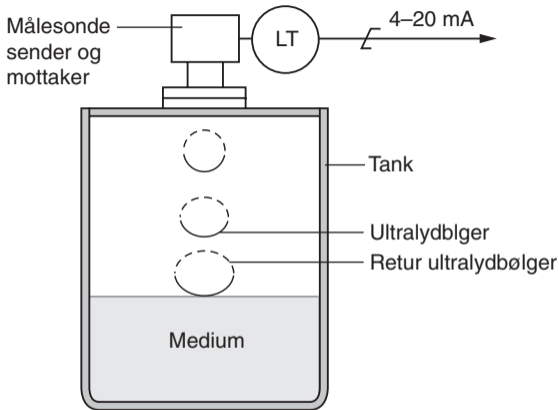
Figur 17.38 Sylinderkondensator



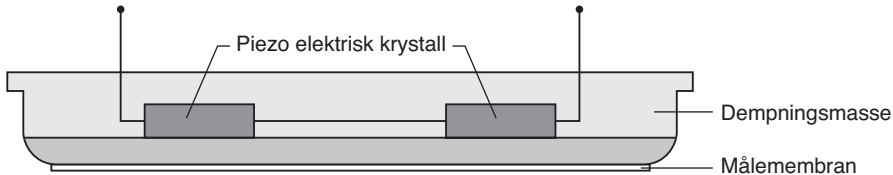
Figur 17.39 Kontinuerlig måling av nivå



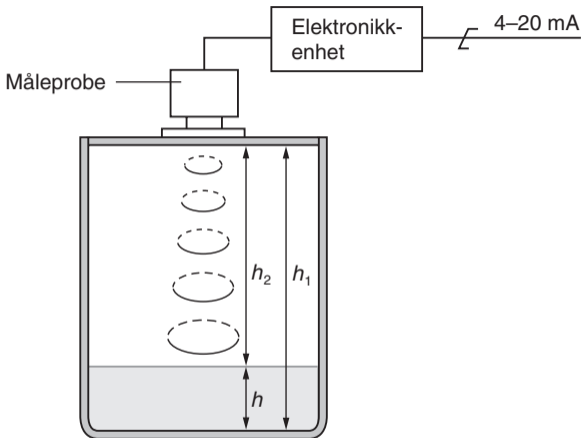
Figur 17.40 Isolert målesonde for måling av nivået i en tank



Figur 17.41 Prinsippet for måling av nivået i en tank med ultralyd



Figur 17.42 Målemembran med påmonterte piezokrystaller



Figur 17.43 Eksempel på måling av nivået i en tank