UNIVERSITY OF MINES AND TECHNOLOGY, TARKWA

FIRST SEMESTER EXAMINATIONS, DEC, 2014

COURSE NO: **PE 375**
COURSE NAME: **NATURAL GAS ENGINEERING**
CLASS: **PE III** TIME: **3 HRS**

Name: ____ Index Number: _______________

INSTRUCTIONS:

Answer **all** questions. Each correct answer in Section A carries 0.5 marks except question 15 which carries 3 marks. Show all the necessary workings on your answer sheets.

Section A

Use the options below to answer (Questions 1 – 7)

gas blow-by	volumetric reservoir	faster
coefficient of compressibility	liquid spillage	water influx
reservoir deliverability	compressibility factor	reservoir
outflow performance relationship	pressure	material balance
configuration of the piping system	lighter	separator pressure

1. The correction factor used to correct a real gas for its departure from ideality is the……
2. The downstream pressure and flow rate relationship is also called …………….
3. When the plot of (p/z) versus Gp deviates from the linear relationship, it indicates……….
4. The flowing bottom hole pressure depends on the ………… and the …………
5. When the level of liquid is too low in separator……….. can occur.
6. Gas wells typically produce raw natural gas by themselves and usually don't require additional lifting equipment because natural gas is …………. than air.

The UMaT FIELD

The UMaT Field operated by PE III Plc has oil with a gas cap hosted in Devonian sandstones. The field is offshore and has a large surface production and processing facility. Fill in the following statements about this field and its operations with your own answers to make the statements valid.

7. The main constituent of the natural gas this company produces is……………………..
8. Because the gas exists together with oil in the reservoir, the gas is an………………….gas.
9. Depending on the phase behaviour of the gas under varying conditions in the reservoir and outside the reservoir, the gas can be classified either as ……………gas, …………………. gas or ………… gas.
10. Gas produced from this field contains a significant amount of hydrogen sulphide. This gas is called ………………….
11. From a technical point of view the components of the facility can be grouped into four types. Two of them are ………………… and …………………
12. As an engineer on this field, explain the three types of gas you listed in question 12 above to a student. (one paragraph, six lines maximum)
13. Due to the offshore location of the field and anticipated limited space, the separator on being used on the platform is likely to be ………………….separator.

State whether following statements are **TRUE** or **FALSE**

14. Recovery factors for water drive gas reservoirs are usually higher than closed gas reservoirs.
15. The ultimate recovery of a volumetric reservoir depends on the production rate.
16. A three stage separation involves three separators.

SECTION B

1 (a) List the factors that determine the gas deviation factor of a given gas. **(3 marks)**

(b) There is 0.65 gravity sour gas in a reservoir with H_2S and CO_2 in 0.1 and 0.05 mole fractions respectively. If the reservoir pressure and temperature are 3200 psia and 200°F, respectively, calculate: (i) gas density and (ii) Specific volume **(10 marks)**

2. (a) A gas well produces 0.65 specific gravity natural gas with N_2, CO_2, and H_2S of mole fractions 0.1, 0.08, and 0.02, respectively. The well diameter is 0.64 ft and drains gas from a 100-ft thick pay zone. The skin factor around the well is 5 and the non-Darcy coefficient is 0.001d/Mscf. The equivalent wellbore radius is 1500 ft, average reservoir pressure is 4500 psia, reservoir temperature is 180 °F and effective permeability of the gas is 0.2md. If the flowing-bottom hole pressure is 3000 psia, what would be the pseudosteady state flow rate of the reservoir using pseudopressure analytical solution? **(4 marks)**

(b) For the reservoir and fluid conditions above, a flow rate test gave the following results:

Test Point 1	
Flow Rate	1000
Bottom Hole Pressure	3000
Test Point 2	
Flow Rate	1500
Bottom Hole Pressure	2000

Estimate the deliverability of the gas reservoir under a pseudosteady state flow condition at a flowing bottom-hole pressure of 1000 psia using pressure squared approach in the back pressure method. **(6 marks)**

(c) Why is the pressure squared approach for calculating flow rates not very reliable at higher pressures? **(2 marks)**

3. (a) What is a volumetric gas reservoir? **(2 marks)**

(b) Discuss the production rate sensitivity of water drive gas reservoirs (six lines maximum). **(3 marks)**

(c) The following information is available on a volumetric gas reservoir: Initial reservoir temperature, T_i = 150°F Initial reservoir pressure, p_i = 3500 psia Specific gravity of gas, γ_g = 0.6 (air = 1) Thickness of reservoir, h = 20 ft Porosity of the reservoir, ϕ= 10% Initial water saturation, S_{wi} = 25%. The initial z_i is 0.86. After producing 300 MMscf, the reservoir pressure declined to 2,500 psia with a corresponding z factor of 0.88. Estimate the areal extent of this reservoir and consequently the gas initially in place. **(9 marks)**

(c) With the production and property data from the reservoir above tabulated below, calculate the gas initially in place using the graphical material balance method. **(8 marks)**

Time, t years	**Reservoir pressure, p psia**	**z**	**Cumulative production, G_p MMMscf**
0.0	1720	0.86	0.0
0.5	1653	0.87	1.0
1.0	1584	0.88	2.0
1.5	1513	0.89	3.0

4. (a) State three assumptions common to all the methods used in calculating the flowing bottom-hole pressure of a well. **(3 marks)**.

(b) Why is the Cullinder and Smith method for calculating bottom-hole pressures the most accurate? **(1 mark)**

(c) Calculate the flowing bottom-hole pressure a dry sweet gas vertical well with the following conditions:

Well depth, Z = 20000 ft

Diameter of tubing, D = 2.00 in.

Moody friction factor, f = 0.016

Reservoir temperature, T_{res} = 900 °R

Surface temperature, T_{surf} = 540 °R

Wellhead pressure, p_{tf} = 14,500 psia

T_{pc} = 470 °R

P_{pc} = 900 psia

Gas flow rate, q = 8.5 MMscfd (at 60°F and 14.65 psia)

Approximate all your T_{pr}, p_{pr} and B values to the nearest higher value published in the tables so that you don't interpolate. **(10 marks)**

5. (a) What are the four main processes in gas processing after it gets to the surface? **(4 marks)**

(b) State one advantage of a horizontal separators and one limitation of spherical separators. **(2 marks)**

(c) (i) Give three reasons why it is necessary to remove water and water vapour from natural gas? **(3 marks)**

(ii) List four methods that can be used to remove or reduce the water content of natural gas. **(2 marks)**

(d) It has been agreed by engineers and management of a sour gas field that the *Sulfinol* process will be used to remove the H_2S, what three factors do you think led them to select this process? **(3 marks)**

6. (a) What are the two main hazards in gas operations? **(2 marks)**

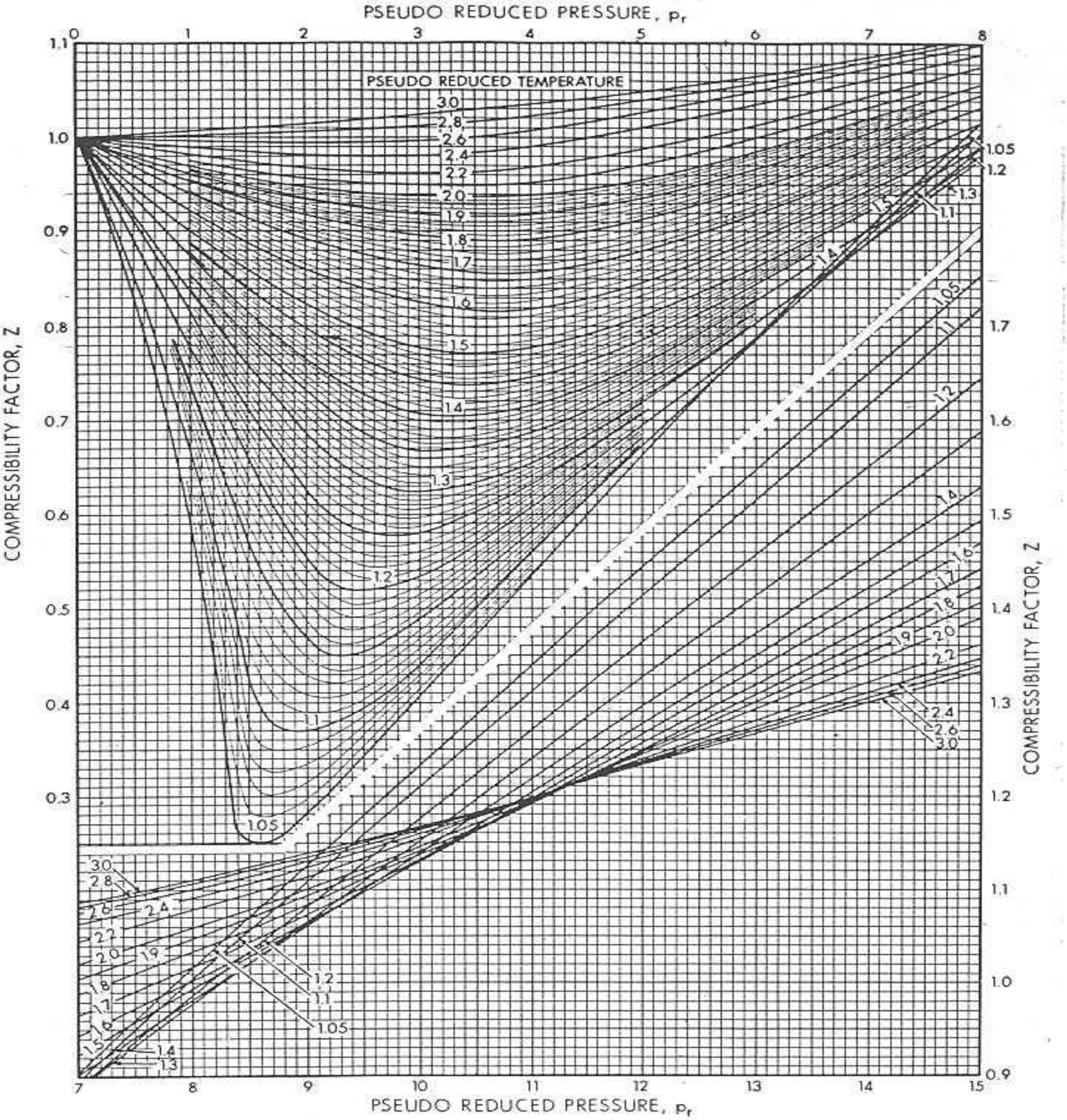
(b) What do safety valves do and in which two ways do they do help in preventing further danger? **(3 marks)**

(c) State three precautions to be taken on gas pipelines. **(3 marks)**

Samuel Tawiah

DATA

$\bar{T} = \dfrac{T_{res} - T_{surf}}{\ln \dfrac{T_{res}}{T_{surf}}}$ = log average temperature **Natural Gas Systems** $T_{pc} = 168 + 325\gamma_g - 12.5\gamma_g^2$ $p_{pc} = 677 + 15.0\gamma_g - 37.5\gamma_g^2$ **Gas-Condensate Systems** $T_{pc} = 187 + 330\gamma_g - 71.5\gamma_g^2$ $p_{pc} = 706 - 51.7\gamma_g - 11.1\gamma_g^2$	$B = \dfrac{667 f q^2 \bar{T}^2}{D^5 p_{pc}{}^2 \cos\theta}$ $\dfrac{\gamma_g L \cos\theta}{53.34\bar{T}} = \int_{(p_{tf})_r}^{(p_{wf})_r} \dfrac{z/p_{pr}}{1 + B(z/p_{pr})^2} dp_{pr}$ $T'_{pc} = T_{pc} - \varepsilon$ $p'_{pc} = \dfrac{p_{pc} T_{pc}{}'}{T_{pc} + B(1 - B)\varepsilon}$ $\varepsilon = 120[A^{0.9} - A^{1.6}] + 15(B^{0.5} - B^{4.0})$
$\rho_g = \dfrac{pM_a}{zRT}$	$B_g = 0.02827 \dfrac{ZT}{P}$ ft^3/scf,
$G = \dfrac{43,560\, Ah\phi(1 - S_{wi})}{B_{gi}}$ $C = \dfrac{q_1}{\left[\bar{p}^2 - p_{wf1}^2\right]^n}$ $B = \dfrac{[m(\bar{p}) - m(p_{wf1})]q_2 - [m(\bar{p}) - m(p_{wf2})]q_1}{q_1^2 q_2 - q_2^2 q_1}$ $A = \dfrac{[m(\bar{p}) - m(p_{wf1})] - Bq_1^2}{q_1}$ $q = \dfrac{kh\left[m(\bar{p}) - m(p_{wf})\right]}{1424T\left[\ln\left(\dfrac{0.472 r_e}{r_w}\right) + s + Dq\right]}$	$G_p = 43,560\, Ah\phi(1 - S_{wi})\left(\dfrac{1}{B_{gi}} - \dfrac{1}{B_{ga}}\right)$ $m(\bar{p}) - m(p_{wf}) = Aq + Bq^2$ $q = C(\bar{p}^2 - p_{wf}^2)^n$ $n = \dfrac{\log\left(\dfrac{q_1}{q_2}\right)}{\log\left(\dfrac{\bar{p}^2 - p_{wf1}^2}{\bar{p}^2 - p_{wf2}^2}\right)}$


PSEUDO REDUCED PRESSURE, p_r
0
1
2
3
4
5
6
7
8
PSEUDO REDUCED TEMPERATURE
3.0
2.8
2.6
2.4
2.2
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.05
COMPRESSIBILITY FACTOR, Z
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
7
8
9
10
11
12
13
14
15
PSEUDO REDUCED PRESSURE, p_r

P_r	Reduced Temperature for B = 15.0														
	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.4	2.6	2.8	3.0
0.20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.50	0.0077	0.0075	0.0074	0.0073	0.0072	0.0071	0.0071	0.0071	0.0070	0.0070	0.0070	0.0070	0.0069	0.0069	0.0069
1.00	0.0385	0.0359	0.0345	0.0336	0.0330	0.0325	0.0322	0.3119	0.0317	0.0316	0.0313	0.0311	0.0310	0.0309	0.0308
1.50	0.0939	0.0838	0.0793	0.0765	0.0746	0.0732	0.0721	0.0713	0.0708	0.0703	0.0696	0.0692	0.0687	0.0685	0.0682
2.00	0.1571	0.1453	0.1371	0.1319	0.1282	0.1257	0.1236	0.1220	0.1211	0.1202	0.1189	0.1180	0.1172	0.1167	0.1161
2.50	0.2162	0.2093	0.2008	0.1943	0.1892	0.1857	0.1827	0.1804	0.1790	0.1777	0.1758	0.1745	0.1733	0.1724	0.1716
3.00	0.2725	0.2710	0.2648	0.2587	0.2533	0.2493	0.2458	0.2431	0.2413	0.2397	0.2374	0.2357	0.2342	0.2331	0.2320
3.50	0.3275	0.3302	0.3267	0.3222	0.3176	0.3138	0.3102	0.3074	0.3055	0.3038	0.3012	0.2994	0.2978	0.2964	0.2952
4.00	0.3818	0.3874	0.3862	0.3837	0.3805	0.3774	0.3743	0.3717	0.3699	0.3683	0.3657	0.3679	0.3622	0.3608	0.3596
4.50	0.4355	0.4430	0.4435	0.4431	0.4415	0.4393	0.4369	0.4349	0.4335	0.4320	0.4298	0.4281	0.4265	0.4252	0.4240
5.00	0.4887	0.4975	0.4992	0.5004	0.5006	0.4994	0.4978	0.4966	0.4956	0.4945	0.4928	0.4914	0.4900	0.4888	0.4877
5.50	0.5413	0.5508	0.5535	0.5561	0.5579	0.5577	0.5570	0.5566	0.5561	0.5554	0.5543	0.5534	0.5522	0.5512	0.5503
6.00	0.5936	0.6034	0.6066	0.6103	0.6135	0.6143	0.6144	0.6149	0.6149	0.6147	0.6143	0.6138	0.6129	0.6121	0.6113
6.50	0.6454	0.6553	0.6590	0.6634	0.6676	0.6694	0.6703	0.6715	0.6720	0.6724	0.6726	0.6727	0.6721	0.6715	0.6708
7.00	0.6969	0.7068	0.7105	0.7155	0.7205	0.7230	0.7246	0.7256	0.7276	0.7284	0.7293	0.7299	0.7296	0.7291	0.7286
7.50	0.7482	0.7577	0.7613	0.7666	0.7722	0.7754	0.7776	0.7802	0.7817	0.7829	0.7844	0.7854	0.7855	0.7852	0.7848
8.00	0.7991	0.8082	0.8114	0.8170	0.8230	0.8266	0.8293	0.8324	0.8344	0.8360	0.8391	0.8395	0.8398	0.8397	0.8394
8.50	0.8497	0.8582	0.8611	0.8666	0.8729	0.8768	0.8799	0.8835	0.8858	0.8878	0.8914	0.8920	0.8926	0.8927	0.8925
9.00	0.9000	0.9078	0.9102	0.9157	0.9220	0.9261	0.9295	0.9334	0.9360	0.9382	0.9423	0.9432	0.9440	0.9442	0.9441
9.50	0.9500	0.9570	0.9588	0.9641	0.9704	0.9746	0.9782	0.9824	0.9852	0.9876	0.9920	0.9932	0.9941	0.9444	0.9944
10.00	0.9998	1.0059	1.0071	1.0121	1.0181	1.0223	1.0260	1.0304	1.0334	1.0359	1.0407	1.0420	1.0430	1.0434	1.0435
10.50	1.0492	1.0544	1.0549	1.0595	1.0653	1.0694	1.0731	1.0776	1.0806	1.0833	1.0883	1.0897	1.0908	1.0913	1.0914
11.00	1.0985	1.1026	1.1024	1.1065	1.1119	1.1159	1.1195	1.1239	1.1271	1.1298	1.1349	1.1364	1.1375	1.1380	1.1381
11.50	1.1475	1.1506	1.1496	1.1530	1.1580	1.1618	1.1653	1.1696	1.1728	1.1755	1.1807	1.1822	1.1832	1.1837	1.1839
12.00	1.1963	1.1983	1.1964	1.1992	1.2037	1.2072	1.2105	1.2147	1.2178	1.2205	1.2256	1.2270	1.2281	1.2285	1.2287
12.50	1.2449	1.2458	1.2430	1.2449	1.2490	1.2522	1.2551	1.2592	1.2622	1.2648	1.2698	1.2711	1.2720	1.2724	1.2725
13.00	1.2934	1.2931	1.2893	1.2903	1.2939	1.2967	1.2993	1.3031	1.3060	1.3084	1.3131	1.3143	1.3152	1.3155	1.3156
13.50	1.3417	1.3402	1.3354	1.3354	1.3384	1.3408	1.3430	1.3465	1.3492	1.3514	1.3558	1.3567	1.3575	1.3578	1.3578
14.00	1.3899	1.3870	1.3812	1.3802	1.3825	1.3845	1.3862	1.3694	1.3918	1.3938	1.3977	1.3984	1.3991	1.3993	1.3992
14.50	1.4380	1.4337	1.4268	1.4247	1.4263	1.4278	1.4290	1.4319	1.4339	1.4356	1.4390	1.4395	1.4400	1.4401	1.4400
15.00	1.4860	1.4803	1.4722	1.4689	1.4698	1.4708	1.4714	1.4739	1.4756	1.4769	1.4797	1.4798	1.4802	1.4802	1.4800
15.50	1.5338	1.5266	1.5174	1.5129	1.5130	1.5135	1.5134	1.5155	1.5168	1.5177	1.5198	1.5196	1.5197	1.5197	1.5194
16.00	1.5815	1.5728	1.5625	1.5566	1.5559	1.5558	1.5551	1.5567	1.5575	1.5580	1.5594	1.5587	1.5587	1.5585	1.5582
16.50	1.6291	1.6189	1.6073	1.6001	1.5985	1.5979	1.5964	1.5976	1.5978	1.5979	1.5984	1.5973	1.5971	1.5968	1.5964
17.00	1.6766	1.6649	1.6520	1.6434	1.6409	1.6397	1.6374	1.6381	1.6378	1.6373	1.6370	1.6354	1.6350	1.6346	1.6341
17.50	1.7241	1.7107	1.6966	1.6865	1.6830	1.6812	1.6781	1.6783	1.6773	1.6764	1.6750	1.6730	1.6723	1.6718	1.6712
18.00	1.7714	1.7564	1.7410	1.7293	1.7249	1.7225	1.7186	1.7181	1.7166	1.7150	1.7127	1.7100	1.7091	1.7085	1.7078
18.50	1.8187	1.8020	1.7853	1.7720	1.7666	1.7635	1.7587	1.7577	1.7554	1.7533	1.7499	1.7466	1.7455	1.7447	1.7439
19.00	1.8659	1.8475	1.8294	1.8146	1.8081	1.8043	1.7986	1.7970	1.7940	1.7912	1.7866	1.7828	1.7814	1.7805	1.7796
19.50	1.9130	1.8929	1.8734	1.8569	1.8493	1.8449	1.8382	1.8360	1.8322	1.8288	1.8230	1.8186	1.8169	1.8158	1.8148
20.00	1.9600	1.9382	1.9173	1.8991	1.8904	1.8853	1.8776	1.8747	1.8702	1.8661	1.8590	1.8540	1.8519	1.8508	1.8496
20.50	2.0070	1.9834	1.9611	1.9412	1.9314	1.9255	1.9168	1.9132	1.9079	1.9031	1.8947	1.8889	1.8866	1.8853	1.8840
21.00	2.0539	2.0285	2.0048	1.9831	1.9721	1.9655	1.9557	1.9515	1.9453	1.9397	1.9300	1.9236	1.9209	1.9195	1.9180
21.50	2.1007	2.0736	2.0484	2.0248	2.0127	2.0054	1.9944	1.9895	1.9824	1.9761	1.9650	1.9578	1.9549	1.9532	1.9517
22.00	2.1475	2.1185	2.0918	2.0665	2.0531	2.0450	2.0330	2.0273	2.0193	2.0122	1.9997	1.9917	1.9884	1.9867	1.9850
22.50	2.1943	2.1634	2.1352	2.1080	2.0934	2.0845	2.0713	2.0649	2.0560	2.0481	2.0341	2.0253	2.0217	2.0148	2.0179
23.00	2.2410	2.2082	2.1785	2.1494	2.1335	2.1239	2.1095	2.1024	2.0924	2.0837	2.0681	2.0586	2.0546	2.0525	2.0506
23.50	2.2876	2.2529	2.2217	2.1906	2.1735	2.1631	2.1475	2.1346	2.1286	2.1191	2.1019	2.0916	2.0872	2.0850	2.0829
24.00	2.3342	2.2976	2.2648	2.2318	2.2134	2.2021	2.1853	2.1766	2.1646	2.1542	2.1355	2.1242	2.1196	2.1171	2.1149
24.50	2.3807	2.3422	2.3079	2.2728	2.2531	2.2410	2.2229	2.2135	2.2005	2.1891	2.1687	2.1567	2.1516	2.1490	2.1466
25.00	2.4272	2.3867	2.3509	2.3138	2.2927	2.2798	2.2604	2.2502	2.2361	2.2238	2.2017	2.1888	2.1834	2.1806	2.1780
25.50	2.4736	2.4312	2.3937	2.3546	2.3322	2.3184	2.2978	2.2867	2.2715	2.2583	2.2345	2.2207	2.2149	2.2119	2.2092
26.00	2.5200	1.4756	2.4366	2.3953	2.3716	2.3569	2.3550	2.3230	2.3067	2.2927	2.2671	2.2523	2.2461	2.2430	2.2401
26.50	2.5664	2.5200	2.4793	2.4360	2.4109	2.3953	2.3720	2.3592	2.3418	2.3268	2.2994	2.2837	2.2771	2.2738	2.2707
27.00	2.6127	2.5643	2.5220	2.4766	2.4501	2.4336	2.4089	2.3953	2.3767	2.3607	2.3315	2.3149	2.3078	2.3044	2.3011
27.50	2.6590	2.6086	2.5646	2.5170	2.4891	2.4718	2.4457	2.4312	2.4115	2.3944	2.3634	2.3458	2.3384	2.3347	2.3313
28.00	2.7053	2.6520	2.6072	2.5574	2.5281	2.5098	2.4824	2.4670	2.4460	2.4280	2.3951	2.3765	2.3687	2.3648	2.3612
28.50	2.7515	2.6969	2.6497	2.5977	2.5669	2.5478	2.5189	2.5026	2.4805	2.4614	2.4266	2.4070	2.3987	2.3947	2.3909
29.00	2.7977	2.7410	2.6921	2.6380	2.6057	2.5856	2.5553	2.5382	2.5148	2.4947	2.4579	2.4373	2.4286	2.4244	2.4205
29.50	2.8438	2.7851	2.7345	2.6781	2.6444	2.6234	2.5916	2.5736	2.5489	2.5278	2.4890	2.4674	2.4583	2.4538	2.4497
30.00	2.8899	2.8291	2.7769	2.7182	2.6830	2.6610	2.6278	2.6088	2.5829	2.5607	2.5200	2.4974	2.4878	2.4831	2.4788