

升举法采油工艺

卷 三 (下)

压力梯度曲线

垂直多相环形空间流动

垂直油管产气

垂直注气

垂直油管注水

[美] K.E. 布朗 主 编

石油工业出版社

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内 容 提 要

本书是卷三(上)的扩展,包括另外一系列压力梯度曲线。由约翰斯顿-麦克瑟,斯伦贝谢(Johnston-Macco Schlumberger)用计算机编制的。叙述垂直多相环形空间流动,垂直油管产气,垂直油管注水,垂直注气等内容。具有广泛的适用性和准确性,简化了以往的繁琐计算,应用这些曲线可以方便地求出井底流压及其它参数。同时,应用这些曲线可以方便地进行油井设备的设计。本书是一本难得的著作,可供从事油田开采的工程技术人员参考使用。

THE TECHNOLOGY OF ARTIFICIAL LIFT METHODS

K. E. Brown

Pennwell Publishing Company Tulsa 1980

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前 言

卷三（下）是由另外的梯度曲线组成，是卷三（上）的扩展，本册包括以下曲线组。

曲线	部分
垂直多相环形空间流动	C
垂直油管产气	D
垂直注气	E
垂直油管注水	F

应用这些曲线的实例将在下面介绍。

我们感谢约翰斯顿-麦克瑟和斯伦贝谢 (Johnston-Macco Schlumberger) 公司提供所有这些用计算机编制的曲线。

本书图表中技术术语英汉对照

Pressure Gradient Curves	压力梯度曲线
Vertical Multiphase Annular Flow	垂直多相环形空间流动
Vertical Tubing Gas Production	垂直油管产气
Vertical Gas Injection	垂直注气
Vertical Tubing Water Injection	垂直油管注水
Pipe Size in	管尺寸 英寸
Percent Oil	含油 %
Rate Oil b/d	产油量 桶/日
Figure Number	图号
Page Number	页码
Wellhead Pressure (Psig)	井口压力 (磅/英寸 ²)
Gas Sp Grav	气比重
Injection Pressure	注入压力
MMSCF/D	百万标准立方英尺/日
TUBING SIZE IN ID.	油管内径 英寸
GAS SPECIFIC GRAVITY	气比重
DEPTH. FT	深度 英尺
RATE MMSCF/D	注气量 百万标准立方英尺/日
PLASTIC COATED PIPES	塑料涂层管
ALL WATER	纯水
AVERAGE FLOWING TEMP	平均流动温度
WATER SPECIFIC GRAVITY	水比重
PSI	磅/英寸 ²
CSG TBG ANNULAR FLOW	套管 油管环形空间流动
OIL API GRAVITY	原油重度 A P I
GAS/LIQUID RATIO SCF PER BBL	气液比 标准立方英尺 / 桶
GAS PRODUCTION	产气量
GAS INJECTION	注气量
VERTICAL FLOWING GAS GRADIENTS	垂直气体流动压力梯度
VERTICAL INJECTION PRESSURE GRADIENTS	垂直注入压力梯度
EXAMPLE PROBLEM	例题

C 部 分

垂直多相环形空间流动

垂直多相环流曲线是采用了海哥顿 (Hagedorn) 和布朗 (Brown) 的相关式编制成的。包括了由 $1.995 \times 1.315 - 12 \times 7$ 英寸的环流尺寸。垂直接动曲线适合于含油 10%、50% 和纯油的液体。其它含油百分比，可采用内插算法。

参考卷一中用垂直多相曲线求解的例题。

见例题 A—1 和 A—2 [卷三 (上)]。

所有可以用油管流动来解的问题也可以用环形空间流动来解。

Vertical Flowing Pressure Gradients

Pipe Size, in.	Percent Oil	Rate, b/d	Figure Number	Page Number	Pipe Size, in.	Percent Oil	Rate, b/d	Figure Number	Page Number
1.995/1.315	10	25	C-1	1	2.441/1.660	10	1,500	C-49	49
1.995/1.315	50	25	C-2	2	2.441/1.660	50	1,500	C-50	50
1.995/1.315	100	25	C-3	3	2.441/1.660	100	1,500	C-51	51
1.995/1.315	10	100	C-4	4	2.441/1.660	10	2,000	C-52	52
1.995/1.315	50	100	C-5	5	2.441/1.660	50	2,000	C-53	53
1.995/1.315	100	100	C-6	6	2.441/1.660	100	2,000	C-54	54
1.995/1.315	10	200	C-7	7	2.441/1.900	10	25	C-55	55
1.995/1.315	50	200	C-8	8	2.441/1.900	50	25	C-56	56
1.995/1.315	100	200	C-9	9	2.441/1.900	100	25	C-57	57
1.995/1.315	10	300	C-10	10	2.441/1.900	10	100	C-58	58
1.995/1.315	50	300	C-11	11	2.441/1.900	50	100	C-59	59
1.995/1.315	100	300	C-12	12	2.441/1.900	100	100	C-60	60
1.995/1.315	10	400	C-13	13	2.441/1.900	10	200	C-61	61
1.995/1.315	50	400	C-14	14	2.441/1.900	50	200	C-62	62
1.995/1.315	100	400	C-15	15	2.441/1.900	100	200	C-63	63
1.995/1.315	10	600	C-16	16	2.441/1.900	10	300	C-64	64
1.995/1.315	50	600	C-17	17	2.441/1.900	50	300	C-65	65
1.995/1.315	100	600	C-18	18	2.441/1.900	100	300	C-66	66
1.995/1.315	10	800	C-19	19	2.441/1.900	10	400	C-67	67
1.995/1.315	50	800	C-20	20	2.441/1.900	50	400	C-68	68
1.995/1.315	100	800	C-21	21	2.441/1.900	100	400	C-69	69
1.995/1.315	10	1,000	C-22	22	2.441/1.900	10	600	C-70	70
1.995/1.315	50	1,000	C-23	23	2.441/1.900	50	600	C-71	71
1.995/1.315	100	1,000	C-24	24	2.441/1.900	100	600	C-72	72
2.441/1.660	10	25	C-25	25	2.441/1.900	10	800	C-73	73
2.441/1.660	50	25	C-26	26	2.441/1.900	50	800	C-74	74
2.441/1.660	100	25	C-27	27	2.441/1.900	100	800	C-75	75
2.441/1.660	10	100	C-28	28	2.441/1.900	10	1,000	C-76	76
2.441/1.660	50	100	C-29	29	2.441/1.900	50	1,000	C-77	77
2.441/1.660	100	100	C-30	30	2.441/1.900	100	1,000	C-78	78
2.441/1.660	10	200	C-31	31	2.441/1.900	10	1,500	C-79	79
2.441/1.660	50	200	C-32	32	2.441/1.900	50	1,500	C-80	80
2.441/1.660	100	200	C-33	33	2.441/1.900	100	1,500	C-81	81
2.441/1.660	10	300	C-34	34	2.441/1.900	10	2,000	C-82	82
2.441/1.660	50	300	C-35	35	2.441/1.900	50	2,000	C-83	83
2.441/1.660	100	300	C-36	36	2.441/1.900	100	2,000	C-84	84
2.441/1.660	10	400	C-37	37	3.920/1.900	10	200	C-85	85
2.441/1.660	50	400	C-38	38	3.920/1.900	50	200	C-86	86
2.441/1.660	100	400	C-39	39	3.920/1.900	100	200	C-87	87
2.441/1.660	10	600	C-40	40	3.920/1.900	10	500	C-88	88
2.441/1.660	50	600	C-41	41	3.920/1.900	50	500	C-89	89
2.441/1.660	100	600	C-42	42	3.920/1.900	100	500	C-90	90
2.441/1.660	10	800	C-43	43	3.920/1.900	10	700	C-91	91
2.441/1.660	50	800	C-44	44	3.920/1.900	50	700	C-92	92
2.441/1.660	100	800	C-45	45	3.920/1.900	100	700	C-93	93
2.441/1.660	10	1,000	C-46	46	3.920/1.900	10	900	C-94	94
2.441/1.660	50	1,000	C-47	47	3.920/1.900	50	900	C-95	95
2.441/1.660	100	1,000	C-48	48	3.920/1.900	100	900	C-96	96

Pipe Size, in.	Percent Oil	Rate, b/d	Figure Number	Page Number	Pipe Size, in.	Percent Oil	Rate, b/d	Figure Number	Page Number
3.920/1.900	10	1,200	C-97	97	4.892/2.375	10	700	C-145	145
3.920/1.900	50	1,200	C-98	98	4.892/2.375	50	700	C-146	146
3.920/1.900	100	1,200	C-99	99	4.892/2.375	100	700	C-147	147
3.920/1.900	10	1,500	C-100	100	4.892/2.375	10	900	C-148	148
3.920/1.900	50	1,500	C-101	101	4.892/2.375	50	900	C-149	149
3.920/1.900	100	1,500	C-102	102	4.892/2.375	100	900	C-150	150
3.920/1.900	10	2,000	C-103	103	4.892/2.375	10	1,200	C-151	151
3.920/1.900	50	2,000	C-104	104	4.892/2.375	50	1,200	C-152	152
3.920/1.900	100	2,000	C-105	105	4.892/2.375	100	1,200	C-153	153
3.920/1.900	10	3,000	C-106	106	4.892/2.375	10	1,500	C-154	154
3.920/1.900	50	3,000	C-107	107	4.892/2.375	50	1,500	C-155	155
3.920/1.900	100	3,000	C-108	108	4.892/2.375	100	1,500	C-156	156
3.920/1.900	10	5,000	C-109	109	4.892/2.375	10	2,000	C-157	157
3.920/1.900	50	5,000	C-110	110	4.892/2.375	50	2,000	C-158	158
3.920/1.900	100	5,000	C-111	111	4.892/2.375	100	2,000	C-159	159
3.920/2.375	10	200	C-112	112	4.892/2.375	10	3,000	C-160	160
3.920/2.375	50	200	C-113	113	4.892/2.375	50	3,000	C-161	161
3.920/2.375	100	200	C-114	114	4.892/2.375	100	3,000	C-162	162
3.920/2.375	10	500	C-115	115	4.892/2.375	10	5,000	C-163	163
3.920/2.375	50	500	C-116	116	4.892/2.375	50	5,000	C-164	164
3.920/2.375	100	500	C-117	117	4.892/2.375	100	5,000	C-165	165
3.920/2.375	10	700	C-118	118	4.892/2.375	10	10,000	C-166	166
3.920/2.375	50	700	C-119	119	4.892/2.375	50	10,000	C-167	167
3.920/2.375	100	700	C-120	120	4.892/2.375	100	10,000	C-168	168
3.920/2.375	10	900	C-121	121	4.892/2.375	10	15,000	C-169	169
3.920/2.375	50	900	C-122	122	4.892/2.375	50	15,000	C-170	170
3.920/2.375	100	900	C-123	123	4.892/2.375	100	15,000	C-171	171
3.920/2.375	10	1,200	C-124	124	4.892/2.875	10	200	C-172	172
3.920/2.375	50	1,200	C-125	125	4.892/2.875	50	200	C-173	173
3.920/2.375	100	1,200	C-126	126	4.892/2.875	100	200	C-174	174
3.920/2.375	10	1,500	C-127	127	4.892/2.875	10	500	C-175	175
3.920/2.375	50	1,500	C-128	128	4.892/2.875	50	500	C-176	176
3.920/2.375	100	1,500	C-129	129	4.892/2.875	100	500	C-177	177
3.920/2.375	10	2,000	C-130	130	4.892/2.875	10	700	C-178	178
3.920/2.375	50	2,000	C-131	131	4.892/2.875	50	700	C-179	179
3.920/2.375	100	2,000	C-132	132	4.892/2.875	100	700	C-180	180
3.920/2.375	10	3,000	C-133	133	4.892/2.875	10	900	C-181	181
3.920/2.375	50	3,000	C-134	134	4.892/2.875	50	900	C-182	182
3.920/2.375	100	3,000	C-135	135	4.892/2.875	100	900	C-183	183
3.920/2.375	10	5,000	C-136	136	4.892/2.875	10	1,200	C-184	184
3.920/2.375	50	5,000	C-137	137	4.892/2.875	50	1,200	C-185	185
3.920/2.375	100	5,000	C-138	138	4.892/2.875	100	1,200	C-186	186
4.892/2.375	10	200	C-139	139	4.892/2.875	10	1,500	C-187	187
4.892/2.375	50	200	C-140	140	4.892/2.875	50	1,500	C-188	188
4.892/2.375	100	200	C-141	141	4.892/2.875	100	1,500	C-189	189
4.892/2.375	10	500	C-142	142	4.892/2.875	10	2,000	C-190	190
4.892/2.375	50	500	C-143	143	4.892/2.875	50	2,000	C-191	191
4.892/2.375	100	500	C-144	144	4.892/2.875	100	2,000	C-192	192

Pipe Size, in.	Percent Oil	Rate, b/d	Figure Number	Page Number	Pipe Size, in.	Percent Oil	Rate, b/d	Figure Number	Page Number
4.892/2.875	10	3,000	C-193	193	6.366/2.875	10	200	C-241	241
4.892/2.875	50	3,000	C-194	194	6.366/2.875	50	200	C-242	242
4.892/2.875	100	3,000	C-195	195	6.366/2.875	100	200	C-243	243
4.892/2.875	10	5,000	C-196	196	6.366/2.875	10	500	C-244	244
4.892/2.875	50	5,000	C-197	197	6.366/2.875	50	500	C-245	245
4.892/2.875	100	5,000	C-198	198	6.366/2.875	100	500	C-246	246
4.892/2.875	10	10,000	C-199	199	6.366/2.875	10	700	C-247	247
4.892/2.875	50	10,000	C-200	200	6.366/2.875	50	700	C-248	248
4.892/2.875	100	10,000	C-201	201	6.366/2.875	100	700	C-249	249
4.892/2.875	10	15,000	C-202	202	6.366/2.875	10	900	C-250	250
4.892/2.875	50	15,000	C-203	203	6.366/2.875	50	900	C-251	251
4.892/2.875	100	15,000	C-204	204	6.366/2.875	100	900	C-252	252
6.366/2.375	10	200	C-205	205	6.366/2.875	10	1,200	C-253	253
6.366/2.375	50	200	C-206	206	6.366/2.875	50	1,200	C-254	254
6.366/2.375	100	200	C-207	207	6.366/2.875	100	1,200	C-255	255
6.366/2.375	10	500	C-208	208	6.366/2.875	10	1,500	C-256	256
6.366/2.375	50	500	C-209	209	6.366/2.875	50	1,500	C-257	257
6.366/2.375	100	500	C-210	210	6.366/2.875	100	1,500	C-258	258
6.366/2.375	10	700	C-211	211	6.366/2.875	10	2,000	C-259	259
6.366/2.375	50	700	C-212	212	6.366/2.875	50	2,000	C-260	260
6.366/2.375	100	700	C-213	213	6.366/2.875	100	2,000	C-261	261
6.366/2.375	10	900	C-214	214	6.366/2.875	10	3,000	C-262	262
6.366/2.375	50	900	C-215	215	6.366/2.875	50	3,000	C-263	263
6.366/2.375	100	900	C-216	216	6.366/2.875	100	3,000	C-264	264
6.366/2.375	10	1,200	C-217	217	6.366/2.875	10	5,000	C-265	265
6.366/2.375	50	1,200	C-218	218	6.366/2.875	50	5,000	C-266	266
6.366/2.375	100	1,200	C-219	219	6.366/2.875	100	5,000	C-267	267
6.366/2.375	10	1,500	C-220	220	6.366/2.875	10	10,000	C-268	268
6.366/2.375	50	1,500	C-221	221	6.366/2.875	50	10,000	C-269	269
6.366/2.375	100	1,500	C-222	222	6.366/2.875	100	10,000	C-270	270
6.366/2.375	10	2,000	C-223	223	6.366/2.875	10	15,000	C-271	271
6.366/2.375	50	2,000	C-224	224	6.366/2.875	50	15,000	C-272	272
6.366/2.375	100	2,000	C-225	225	6.366/2.875	100	15,000	C-273	273
6.366/2.375	10	3,000	C-226	226	6.366/2.875	10	20,000	C-274	274
6.366/2.375	50	3,000	C-227	227	6.366/2.875	50	20,000	C-275	275
6.366/2.375	100	3,000	C-228	228	6.366/2.875	100	20,000	C-276	276
6.366/2.375	10	5,000	C-229	229	6.366/3.500	10	200	C-277	277
6.366/2.375	50	5,000	C-230	230	6.366/3.500	50	200	C-278	278
6.366/2.375	100	5,000	C-231	231	6.366/3.500	100	200	C-279	279
6.366/2.375	10	10,000	C-232	232	6.366/3.500	10	500	C-280	280
6.366/2.375	50	10,000	C-233	233	6.366/3.500	50	500	C-281	281
6.366/2.375	100	10,000	C-234	234	6.366/3.500	100	500	C-282	282
6.366/2.375	10	15,000	C-235	235	6.366/3.500	10	700	C-283	283
6.366/2.375	50	15,000	C-236	236	6.366/3.500	50	700	C-284	284
6.366/2.375	100	15,000	C-237	237	6.366/3.500	100	700	C-285	285
6.366/2.375	10	20,000	C-238	238	6.366/3.500	10	900	C-286	286
6.366/2.375	50	20,000	C-239	239	6.366/3.500	50	900	C-287	287
6.366/2.375	100	20,000	C-240	240	6.366/3.500	100	900	C-288	288

Pipe Size, in.	Percent Oil	Rate, b/d	Figure Number	Page Number	Pipe Size, in.	Percent Oil	Rate, b/d	Figure Number	Page Number
6.366/3.500	10	1,200	C-289	289	8.921/2.875	10	5,000	C-337	337
6.366/3.500	50	1,200	C-290	290	8.921/2.875	50	5,000	C-338	338
6.366/3.500	100	1,200	C-291	291	8.921/2.875	100	5,000	C-339	339
6.366/3.500	10	1,500	C-292	292	8.921/2.875	10	10,000	C-340	340
6.366/3.500	50	1,500	C-293	293	8.921/2.875	50	10,000	C-341	341
6.366/3.500	100	1,500	C-294	294	8.921/2.875	100	10,000	C-342	342
6.366/3.500	10	2,000	C-295	295	8.921/2.875	10	15,000	C-343	343
6.366/3.500	50	2,000	C-296	296	8.921/2.875	50	15,000	C-344	344
6.366/3.500	100	2,000	C-297	297	8.921/2.875	100	15,000	C-345	345
6.366/3.500	10	3,000	C-298	298	8.921/2.875	10	20,000	C-346	346
6.366/3.500	50	3,000	C-299	299	8.921/2.875	50	20,000	C-347	347
6.366/3.500	100	3,000	C-300	300	8.921/2.875	100	20,000	C-348	348
6.366/3.500	10	5,000	C-301	301	8.921/2.875	10	30,000	C-349	349
6.366/3.500	50	5,000	C-302	302	8.921/2.875	50	30,000	C-350	350
6.366/3.500	100	5,000	C-303	303	8.921/2.875	100	30,000	C-351	351
6.366/3.500	10	10,000	C-304	304	8.921/2.875	10	50,000	C-352	352
6.366/3.500	50	10,000	C-305	305	8.921/2.875	50	50,000	C-353	353
6.366/3.500	100	10,000	C-306	306	8.921/2.875	100	50,000	C-354	354
6.366/3.500	10	15,000	C-307	307	8.921/2.875	10	60,000	C-355	355
6.366/3.500	50	15,000	C-308	308	8.921/2.875	50	60,000	C-356	356
6.366/3.500	100	15,000	C-309	309	8.921/2.875	100	60,000	C-357	357
6.366/3.500	10	20,000	C-310	310	8.921/3.500	10	200	C-358	358
6.366/3.500	50	20,000	C-311	311	8.921/3.500	50	200	C-359	359
6.366/3.500	100	20,000	C-312	312	8.921/3.500	100	200	C-360	360
8.921/2.875	10	200	C-313	313	8.921/3.500	10	500	C-361	361
8.921/2.875	50	200	C-314	314	8.921/3.500	50	500	C-362	362
8.921/2.875	100	200	C-315	315	8.921/3.500	100	500	C-363	363
8.921/2.875	10	500	C-316	316	8.921/3.500	10	700	C-364	364
8.921/2.875	50	500	C-317	317	8.921/3.500	50	700	C-365	365
8.921/2.875	100	500	C-318	318	8.921/3.500	100	700	C-366	366
8.921/2.875	10	700	C-319	319	8.921/3.500	10	900	C-367	367
8.921/2.875	50	700	C-320	320	8.921/3.500	50	900	C-368	368
8.921/2.875	100	700	C-321	321	8.921/3.500	100	900	C-369	369
8.921/2.875	10	900	C-322	322	8.921/3.500	10	1,200	C-370	370
8.921/2.875	50	900	C-323	323	8.921/3.500	50	1,200	C-371	371
8.921/2.875	100	900	C-324	324	8.921/3.500	100	1,200	C-372	372
8.921/2.875	10	1,200	C-325	325	8.921/3.500	10	1,500	C-373	373
8.921/2.875	50	1,200	C-326	326	8.921/3.500	50	1,500	C-374	374
8.921/2.875	100	1,200	C-327	327	8.921/3.500	100	1,500	C-375	375
8.921/2.875	10	1,500	C-328	328	8.921/3.500	10	2,000	C-376	376
8.921/2.875	50	1,500	C-329	329	8.921/3.500	50	2,000	C-377	377
8.921/2.875	100	1,500	C-330	330	8.921/3.500	100	2,000	C-378	378
8.921/2.875	10	2,000	C-331	331	8.921/3.500	10	3,000	C-379	379
8.921/2.875	50	2,000	C-332	332	8.921/3.500	50	3,000	C-380	380
8.921/2.875	100	2,000	C-333	333	8.921/3.500	100	3,000	C-381	381
8.921/2.875	10	3,000	C-334	334	8.921/3.500	10	5,000	C-382	382
8.921/2.875	50	3,000	C-335	335	8.921/3.500	50	5,000	C-383	383
8.921/2.875	100	3,000	C-336	336	8.921/3.500	100	5,000	C-384	384

Pipe Size, in.	Percent Oil	Rate, b/d	Figure Number	Page Number	Pipe Size, in.	Percent Oil	Rate, b/d	Figure Number	Page Number
8.921/3.500	10	10,000	C-385	385	8.921/4.500	10	15,000	C-433	433
8.921/3.500	50	10,000	C-386	386	8.921/4.500	50	15,000	C-434	434
8.921/3.500	100	10,000	C-387	387	8.921/4.500	100	15,000	C-435	435
8.921/3.500	10	15,000	C-388	388	8.921/4.500	10	20,000	C-436	436
8.921/3.500	50	15,000	C-389	389	8.921/4.500	50	20,000	C-437	437
8.921/3.500	100	15,000	C-390	390	8.921/4.500	100	20,000	C-438	438
8.921/3.500	10	20,000	C-391	391	8.921/4.500	10	30,000	C-439	439
8.921/3.500	50	20,000	C-392	392	8.921/4.500	50	30,000	C-440	440
8.921/3.500	100	20,000	C-393	393	8.921/4.500	100	30,000	C-441	441
8.921/3.500	10	30,000	C-394	394	8.921/4.500	10	50,000	C-442	442
8.921/3.500	50	30,000	C-395	395	8.921/4.500	50	50,000	C-443	443
8.921/3.500	100	30,000	C-396	396	8.921/4.500	100	50,000	C-444	444
8.921/3.500	10	50,000	C-397	397	8.921/4.500	10	60,000	C-445	445
8.921/3.500	50	50,000	C-398	398	8.921/4.500	50	60,000	C-446	446
8.921/3.500	100	50,000	C-399	399	8.921/4.500	100	60,000	C-447	447
8.921/3.500	10	60,000	C-400	400	8.921/5.000	10	200	C-448	448
8.921/3.500	50	60,000	C-401	401	8.921/5.000	50	200	C-449	449
8.921/3.500	100	60,000	C-402	402	8.921/5.000	100	200	C-450	450
8.921/4.500	10	200	C-403	403	8.921/5.000	10	500	C-451	451
8.921/4.500	50	200	C-404	404	8.921/5.000	50	500	C-452	452
8.921/4.500	100	200	C-405	405	8.921/5.000	100	500	C-453	453
8.921/4.500	10	500	C-406	406	8.921/5.000	10	700	C-454	454
8.921/4.500	50	500	C-407	407	8.921/5.000	50	700	C-455	455
8.921/4.500	100	500	C-408	408	8.921/5.000	100	700	C-456	456
8.921/4.500	10	700	C-409	409	8.921/5.000	10	900	C-457	457
8.921/4.500	50	700	C-410	410	8.921/5.000	50	900	C-458	458
8.921/4.500	100	700	C-411	411	8.921/5.000	100	900	C-459	459
8.921/4.500	10	900	C-412	412	8.921/5.000	10	1,200	C-460	460
8.921/4.500	50	900	C-413	413	8.921/5.000	50	1,200	C-461	461
8.921/4.500	100	900	C-414	414	8.921/5.000	100	1,200	C-462	462
8.921/4.500	10	1,200	C-415	415	8.921/5.000	10	1,500	C-463	463
8.921/4.500	50	1,200	C-416	416	8.921/5.000	50	1,500	C-464	464
8.921/4.500	100	1,200	C-417	417	8.921/5.000	100	1,500	C-465	465
8.921/4.500	10	1,500	C-418	418	8.921/5.000	10	2,000	C-466	466
8.921/4.500	50	1,500	C-419	419	8.921/5.000	50	2,000	C-467	467
8.921/4.500	100	1,500	C-420	420	8.921/5.000	100	2,000	C-468	468
8.921/4.500	10	2,000	C-421	421	8.921/5.000	10	3,000	C-469	469
8.921/4.500	50	2,000	C-422	422	8.921/5.000	50	3,000	C-470	470
8.921/4.500	100	2,000	C-423	423	8.921/5.000	100	3,000	C-471	471
8.921/4.500	10	3,000	C-424	424	8.921/5.000	10	5,000	C-472	472
8.921/4.500	50	3,000	C-425	425	8.921/5.000	50	5,000	C-473	473
8.921/4.500	100	3,000	C-426	426	8.921/5.000	100	5,000	C-474	474
8.921/4.500	10	5,000	C-427	427	8.921/5.000	10	10,000	C-475	475
8.921/4.500	50	5,000	C-428	428	8.921/5.000	50	10,000	C-476	476
8.921/4.500	100	5,000	C-429	429	8.921/5.000	100	10,000	C-477	477
8.921/4.500	10	10,000	C-430	430	8.921/5.000	10	15,000	C-478	478
8.921/4.500	50	10,000	C-431	431	8.921/5.000	50	15,000	C-479	479
8.921/4.500	100	10,000	C-432	432	8.921/5.000	100	15,000	C-480	480

Pipe Size in.	Percent Oil	Rate, b/d	Figure Number	Page Number	Pipe Size in.	Percent Oil	Rate, b/d	Figure Number	Page Number
8.921/5.000	10	20,000	C-481	481	10.050/3.500	10	30,000	C-529	529
8.921/5.000	50	20,000	C-482	482	10.050/3.500	50	30,000	C-530	530
8.921/5.000	100	20,000	C-483	483	10.050/3.500	100	30,000	C-531	531
8.921/5.000	10	30,000	C-484	484	10.050/3.500	10	50,000	C-532	532
8.921/5.000	50	30,000	C-485	485	10.050/3.500	50	50,000	C-533	533
8.921/5.000	100	30,000	C-486	486	10.050/3.500	100	50,000	C-534	534
8.921/5.000	10	50,000	C-487	487	10.050/3.500	10	60,000	C-535	535
8.921/5.000	50	50,000	C-488	488	10.050/3.500	50	60,000	C-536	536
8.921/5.000	100	50,000	C-489	489	10.050/3.500	100	60,000	C-537	537
8.921/5.000	10	60,000	C-490	490	10.050/3.500	10	75,000	C-538	538
8.921/5.000	50	60,000	C-491	491	10.050/3.500	50	75,000	C-539	539
8.921/5.000	100	60,000	C-492	492	10.050/3.500	100	75,000	C-540	540
10.050/3.500	10	200	C-493	493	10.050/4.500	10	200	C-541	541
10.050/3.500	50	200	C-494	494	10.050/4.500	50	200	C-542	542
10.050/3.500	100	200	C-495	495	10.050/4.500	100	200	C-543	543
10.050/3.500	10	500	C-496	496	10.050/4.500	10	500	C-544	544
10.050/3.500	50	500	C-497	497	10.050/4.500	50	500	C-545	545
10.050/3.500	100	500	C-498	498	10.050/4.500	100	500	C-546	546
10.050/3.500	10	700	C-499	499	10.050/4.500	10	700	C-547	547
10.050/3.500	50	700	C-500	500	10.050/4.500	50	700	C-548	548
10.050/3.500	100	700	C-501	501	10.050/4.500	100	700	C-549	549
10.050/3.500	10	900	C-502	502	10.050/4.500	10	900	C-550	550
10.050/3.500	50	900	C-503	503	10.050/4.500	50	900	C-551	551
10.050/3.500	100	900	C-504	504	10.050/4.500	100	900	C-552	552
10.050/3.500	10	1,200	C-505	505	10.050/4.500	10	1,200	C-553	553
10.050/3.500	50	1,200	C-506	506	10.050/4.500	50	1,200	C-554	554
10.050/3.500	100	1,200	C-507	507	10.050/4.500	100	1,200	C-555	555
10.050/3.500	10	1,500	C-508	508	10.050/4.500	10	1,500	C-556	556
10.050/3.500	50	1,500	C-509	509	10.050/4.500	50	1,500	C-557	557
10.050/3.500	100	1,500	C-510	510	10.050/4.500	100	1,500	C-558	558
10.050/3.500	10	2,000	C-511	511	10.050/4.500	10	2,000	C-559	559
10.050/3.500	50	2,000	C-512	512	10.050/4.500	50	2,000	C-560	560
10.050/3.500	100	2,000	C-513	513	10.050/4.500	100	2,000	C-561	561
10.050/3.500	10	3,000	C-514	514	10.050/4.500	10	3,000	C-562	562
10.050/3.500	50	3,000	C-515	515	10.050/4.500	50	3,000	C-563	563
10.050/3.500	100	3,000	C-516	516	10.050/4.500	100	3,000	C-564	564
10.050/3.500	10	5,000	C-517	517	10.050/4.500	10	5,000	C-565	565
10.050/3.500	50	5,000	C-518	518	10.050/4.500	50	5,000	C-566	566
10.050/3.500	100	5,000	C-519	519	10.050/4.500	100	5,000	C-567	567
10.050/3.500	10	10,000	C-520	520	10.050/4.500	10	10,000	C-568	568
10.050/3.500	50	10,000	C-521	521	10.050/4.500	50	10,000	C-569	569
10.050/3.500	100	10,000	C-522	522	10.050/4.500	100	10,000	C-570	570
10.050/3.500	10	15,000	C-523	523	10.050/4.500	10	15,000	C-571	571
10.050/3.500	50	15,000	C-524	524	10.050/4.500	50	15,000	C-572	572
10.050/3.500	100	15,000	C-525	525	10.050/4.500	100	15,000	C-573	573
10.050/3.500	10	20,000	C-526	526	10.050/4.500	10	20,000	C-574	574
10.050/3.500	50	20,000	C-527	527	10.050/4.500	50	20,000	C-575	575
10.050/3.500	100	20,000	C-528	528	10.050/4.500	100	20,000	C-576	576

Pipe Size In.	Percent Oil	Rate, b/d	Figure Number	Page Number	Pipe Size In.	Percent Oil	Rate, b/d	Figure Number	Page Number
10.050/4.500	10	30,000	C-577	577	10.050/5.000	10	30,000	C-625	625
10.050/4.500	50	30,000	C-578	578	10.050/5.000	50	30,000	C-626	626
10.050/4.500	100	30,000	C-579	579	10.050/5.000	100	30,000	C-627	627
10.050/4.500	10	50,000	C-580	580	10.050/5.000	10	50,000	C-628	628
10.050/4.500	50	50,000	C-581	581	10.050/5.000	50	50,000	C-629	629
10.050/4.500	100	50,000	C-582	582	10.050/5.000	100	50,000	C-630	630
10.050/4.500	10	60,000	C-583	583	10.050/5.000	10	50,000	C-631	631
10.050/4.500	50	60,000	C-584	584	10.050/5.000	50	60,000	C-632	632
10.050/4.500	100	60,000	C-585	585	10.050/5.000	100	60,000	C-633	633
10.050/4.500	10	75,000	C-586	586	10.050/5.000	10	75,000	C-634	634
10.050/4.500	50	75,000	C-587	587	10.050/5.000	50	75,000	C-635	635
10.050/4.500	100	75,000	C-588	588	10.050/5.000	100	75,000	C-636	636
10.050/5.000	10	200	C-589	589	12.000/3.500	10	200	C-637	637
10.050/5.000	50	200	C-590	590	12.000/3.500	50	200	C-638	638
10.050/5.000	100	200	C-591	591	12.000/3.500	100	200	C-639	639
10.050/5.000	10	500	C-592	592	12.000/3.500	10	500	C-640	640
10.050/5.000	50	500	C-593	593	12.000/3.500	50	500	C-641	641
10.050/5.000	100	500	C-594	594	12.000/3.500	100	500	C-642	642
10.050/5.000	10	700	C-595	595	12.000/3.500	10	700	C-643	643
10.050/5.000	50	700	C-596	596	12.000/3.500	50	700	C-644	644
10.050/5.000	100	700	C-597	597	12.000/3.500	100	700	C-645	645
10.050/5.000	10	900	C-598	598	12.000/3.500	10	900	C-646	646
10.050/5.000	50	900	C-599	599	12.000/3.500	50	900	C-647	647
10.050/5.000	100	900	C-600	600	12.000/3.500	100	900	C-648	648
10.050/5.000	10	1,200	C-601	601	12.000/3.500	10	1,200	C-649	649
10.050/5.000	50	1,200	C-602	602	12.000/3.500	50	1,200	C-650	650
10.050/5.000	100	1,200	C-603	603	12.000/3.500	100	1,200	C-651	651
10.050/5.000	10	1,500	C-604	604	12.000/3.500	10	1,500	C-652	652
10.050/5.000	50	1,500	C-605	605	12.000/3.500	50	1,500	C-653	653
10.050/5.000	100	1,500	C-606	606	12.000/3.500	100	1,500	C-654	654
10.050/5.000	10	2,000	C-607	607	12.000/3.500	10	2,000	C-655	655
10.050/5.000	50	2,000	C-608	608	12.000/3.500	50	2,000	C-656	656
10.050/5.000	100	2,000	C-609	609	12.000/3.500	100	2,000	C-657	657
10.050/5.000	10	3,000	C-610	610	12.000/3.500	10	3,000	C-658	658
10.050/5.000	50	3,000	C-611	611	12.000/3.500	50	3,000	C-659	659
10.050/5.000	100	3,000	C-612	612	12.000/3.500	100	3,000	C-660	660
10.050/5.000	10	5,000	C-613	613	12.000/3.500	10	5,000	C-661	661
10.050/5.000	50	5,000	C-614	614	12.000/3.500	50	5,000	C-662	662
10.050/5.000	100	5,000	C-615	615	12.000/3.500	100	5,000	C-663	663
10.060/5.000	10	10,000	C-616	616	12.000/3.500	10	10,000	C-664	664
10.050/5.000	50	10,000	C-617	617	12.000/3.500	50	10,000	C-665	665
10.050/5.000	100	10,000	C-618	618	12.000/3.500	100	10,000	C-666	666
10.050/5.000	10	15,000	C-619	619	12.000/3.500	10	15,000	C-667	667
10.050/5.000	50	15,000	C-620	620	12.000/3.500	50	15,000	C-668	668
10.050/5.000	100	15,000	C-621	621	12.000/3.500	100	15,000	C-669	669
10.050/5.000	10	20,000	C-622	622	12.000/3.500	10	20,000	C-670	670
10.050/5.000	50	20,000	C-623	623	12.000/3.500	50	20,000	C-671	671
10.050/5.000	100	20,000	C-624	624	12.000/3.500	100	20,000	C-672	672

Pipe Size In.	Percent Oil	Rate, b/d	Figure Number	Page Number	Pipe Size In.	Percent Oil	Rate, b/d	Figure Number	Page Number
12.000/3.500	10	30,000	C-673	673	12.000/4.500	10	20,000	C-721	721
12.000/3.500	50	30,000	C-674	674	12.000/4.500	50	20,000	C-722	722
12.000/3.500	100	30,000	C-675	675	12.000/4.500	100	20,000	C-723	723
12.000/3.500	10	50,000	C-676	676	12.000/4.500	10	30,000	C-724	724
12.000/3.500	50	50,000	C-677	677	12.000/4.500	50	30,000	C-725	725
12.000/3.500	100	50,000	C-678	678	12.000/4.500	100	30,000	C-726	726
12.000/3.500	10	60,000	C-679	679	12.000/4.500	10	50,000	C-727	727
12.000/3.500	50	60,000	C-680	680	12.000/4.500	50	50,000	C-728	728
12.000/3.500	100	60,000	C-681	681	12.000/4.500	100	50,000	C-729	729
12.000/3.500	10	75,000	C-682	682	12.000/4.500	10	60,000	C-730	730
12.000/3.500	50	75,000	C-683	683	12.000/4.500	50	60,000	C-731	731
12.000/3.500	100	75,000	C-684	684	12.000/4.500	100	60,000	C-732	732
12.000/3.500	10	100,000	C-685	685	12.000/4.500	10	75,000	C-733	733
12.000/3.500	50	100,000	C-686	686	12.000/4.500	50	75,000	C-734	734
12.000/3.500	100	100,000	C-687	687	12.000/4.500	100	75,000	C-735	735
12.000/4.500	10	200	C-688	688	12.000/4.500	10	100,000	C-736	736
12.000/4.500	50	200	C-689	689	12.000/4.500	50	100,000	C-737	737
12.000/4.500	100	200	C-690	690	12.000/4.500	100	100,000	C-738	738
12.000/4.500	10	500	C-691	691	12.000/5.500	10	200	C-739	739
12.000/4.500	50	500	C-692	692	12.000/5.500	50	200	C-740	740
12.000/4.500	100	500	C-693	693	12.000/5.500	100	200	C-741	741
12.000/4.500	10	700	C-694	694	12.000/5.500	10	500	C-742	742
12.000/4.500	50	700	C-695	695	12.000/5.500	50	500	C-743	743
12.000/4.500	100	700	C-696	696	12.000/5.500	100	500	C-744	744
12.000/4.500	10	900	C-697	697	12.000/5.500	10	700	C-745	745
12.000/4.500	50	900	C-698	698	12.000/5.500	50	700	C-746	746
12.000/4.500	100	900	C-699	699	12.000/5.500	100	700	C-747	747
12.000/4.500	10	1,200	C-700	700	12.000/5.500	10	900	C-748	748
12.000/4.500	50	1,200	C-701	701	12.000/5.500	50	900	C-749	749
12.000/4.500	100	1,200	C-702	702	12.000/5.500	100	900	C-750	750
12.000/4.500	10	1,500	C-703	703	12.000/5.500	10	1,200	C-751	751
12.000/4.500	50	1,500	C-704	704	12.000/5.500	50	1,200	C-752	752
12.000/4.500	100	1,500	C-705	705	12.000/5.500	100	1,200	C-753	753
12.000/4.500	10	2,000	C-706	706	12.000/5.500	10	1,500	C-754	754
12.000/4.500	50	2,000	C-707	707	12.000/5.500	50	1,500	C-755	755
12.000/4.500	100	2,000	C-708	708	12.000/5.500	100	1,500	C-756	756
12.000/4.500	10	3,000	C-709	709	12.000/5.500	10	2,000	C-757	757
12.000/4.500	50	3,000	C-710	710	12.000/5.500	50	2,000	C-758	758
12.000/4.500	100	3,000	C-711	711	12.000/5.500	100	2,000	C-759	759
12.000/4.500	10	5,000	C-712	712	12.000/5.500	10	3,000	C-760	760
12.000/4.500	50	5,000	C-713	713	12.000/5.500	50	3,000	C-761	761
12.000/4.500	100	5,000	C-714	714	12.000/5.500	100	3,000	C-762	762
12.000/4.500	10	10,000	C-715	715	12.000/5.500	10	5,000	C-763	763
12.000/4.500	50	10,000	C-716	716	12.000/5.500	50	5,000	C-764	764
12.000/4.500	100	10,000	C-717	717	12.000/5.500	100	5,000	C-765	765
12.000/4.500	10	15,000	C-718	718	12.000/5.500	10	10,000	C-766	766
12.000/4.500	50	15,000	C-719	719	12.000/5.500	50	10,000	C-767	767
12.000/4.500	100	15,000	C-720	720	12.000/5.500	100	10,000	C-768	768

Pipe Size in.	Percent Oil	Rate, b/d	Figure Number	Page Number	Pipe Size in.	Percent Oil	Rate, b/d	Figure Number	Page Number
12.000/5.500	10	15,000	C-769	769	12.000/7.000	10	1,500	C-805	805
12.000/5.500	50	15,000	C-770	770	12.000/7.000	50	1,500	C-806	806
12.000/5.500	100	15,000	C-771	771	12.000/7.000	100	1,500	C-807	807
12.000/5.500	10	20,000	C-772	772	12.000/7.000	10	2,000	C-808	808
12.000/5.500	50	20,000	C-773	773	12.000/7.000	50	2,000	C-809	809
12.000/5.500	100	20,000	C-774	774	12.000/7.000	100	2,000	C-810	810
12.000/5.500	10	30,000	C-775	775	12.000/7.000	10	3,000	C-811	811
12.000/5.500	50	30,000	C-776	776	12.000/7.000	50	3,000	C-812	812
12.000/5.500	100	30,000	C-777	777	12.000/7.000	100	3,000	C-813	813
12.000/5.500	10	50,000	C-778	778	12.000/7.000	10	5,000	C-814	814
12.000/5.500	50	50,000	C-779	779	12.000/7.000	50	5,000	C-815	815
12.000/5.500	100	50,000	C-780	780	12.000/7.000	100	5,000	C-816	816
12.000/5.500	10	60,000	C-781	781	12.000/7.000	10	10,000	C-817	817
12.000/5.500	50	60,000	C-782	782	12.000/7.000	50	10,000	C-818	818
12.000/5.500	100	60,000	C-783	783	12.000/7.000	100	10,000	C-819	819
12.000/5.500	10	75,000	C-784	784	12.000/7.000	10	15,000	C-820	820
12.000/5.500	50	75,000	C-785	785	12.000/7.000	50	15,000	C-821	821
12.000/5.500	100	75,000	C-786	786	12.000/7.000	100	15,000	C-822	822
12.000/5.500	10	100,000	C-787	787	12.000/7.000	10	20,000	C-823	823
12.000/5.500	50	100,000	C-788	788	12.000/7.000	50	20,000	C-824	824
12.000/5.500	100	100,000	C-789	789	12.000/7.000	100	20,000	C-825	825
12.000/7.000	10	200	C-790	790	12.000/7.000	10	30,000	C-826	826
12.000/7.000	50	200	C-791	791	12.000/7.000	50	30,000	C-827	827
12.000/7.000	100	200	C-792	792	12.000/7.000	100	30,000	C-828	828
12.000/7.000	10	500	C-793	793	12.000/7.000	10	50,000	C-829	829
12.000/7.000	50	500	C-794	794	12.000/7.000	50	50,000	C-830	830
12.000/7.000	100	500	C-795	795	12.000/7.000	100	50,000	C-831	831
12.000/7.000	10	700	C-796	796	12.000/7.000	10	60,000	C-832	832
12.000/7.000	50	700	C-797	797	12.000/7.000	50	60,000	C-833	833
12.000/7.000	100	700	C-798	798	12.000/7.000	100	60,000	C-834	834
12.000/7.000	10	900	C-799	799	12.000/7.000	10	75,000	C-835	835
12.000/7.000	50	900	C-800	800	12.000/7.000	50	75,000	C-836	836
12.000/7.000	100	900	C-801	801	12.000/7.000	100	75,000	C-837	837
2.000/7.000	10	1,200	C-802	802	12.000/7.000	10	100,000	C-838	838
2.000/7.000	50	1,200	C-803	803	12.000/7.000	50	100,000	C-839	839
2.000/7.000	100	1,200	C-804	804	12.000/7.000	100	100,000	C-840	840

D 部 分

垂直油管产气

垂直油管产气曲线是采用库兰德 (Cullender) 和史密斯 (Smith) 的相关式绘制成的。与油田实际情况对比, 该相关式对于干气及中等程度干气流来讲很适用。当液气比低于50000标准立方英尺/桶时, 推荐采用贝格斯和布里尔 (Beggs, Brill) 或埃兹兹 (Aziz) 等人的多相流相关式。

例题D-1: 确定井底流动压力

已知:

井口压力 = 1200磅/英寸²

油管尺寸 = 2.992英寸 (内径)

气体比重 = 0.65

井深 = 10000英尺

产量 = 15百万标准立方英尺/日

求: 井底流动压力 (见图D-59)

解: 1. 求出井口压力为1200磅/英寸²所对应的等深度。由1200磅/英寸²垂直向下直到与15百万立方英尺/日产量曲线相交, 并记录该交点深度为2400英尺。

2. 将2400英尺的深度与10000英尺井深相加即得到12400英尺。

3. 由12400英尺深度 (垂直) 平行前进交于15百万标准立方英尺/日流量线可得流动压力读数为2020磅/英寸²。

