ORGANIZATION OF REACTION ENGINEERING PROBLEMS

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THE PRACTICE OF ENGINEERING, like the natural sciences, involves many quantitative relationships and operations. Hence, education in this field includes many, hopefully realistic, exercises using these relationships. These exercises generally take the form of problems intended to illustrate or reinforce a given concept, and are used as homework assignments, lecture demonstrations and examination topics. There are many areas in chemical engineering, including reaction engineering, in which quantitative problems are employed more or less extensively in the educational process.

The instructor of ChE, particularly one who specializes in a given field such as reaction engineering and who regularly teaches in this field, rapidly accumulates a copious set of quantitative problems for the purposes mentioned above. After some time, the organization and management of these resources can become an unwieldy and frustrating task. In particular, the operation of information retrieval, as it applies to the act of selecting a problem for the purpose of illustrating a given concept, often requires more than just a good memory (especially if some variety is hoped for in course offerings). Thus, the purpose of this article is to describe an efficient, manual method for organizing reaction engineering problems, based upon the key concept method of information retrieval.

As its name suggests, the key concept method requires, firstly, the identification of a number of terms pertaining to various concepts of interest. In a large general field such as ChE, hundreds of such terms would be necessary for an efficient information retrieval system, and computer methods, rather than manual, would be almost essential. For a relatively specialized application, however, such as the organization

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of reaction engineering problems, the list of identifying concepts can be kept to a size easily manageable by manual methods. As an aside, the very act of organizing the subject matter of a given field into such key concepts is, by itself, a very valuable aid in the structuring of a course into modular units.

The usage of the key concept method for information retrieval has been described by numerous authors (1-4). After the key concept words for a given application have been selected, a table form, typically an index card, is set up for each such key concept. Items to be accessed via this system are then assigned code numbers which are essentially arbitrary; the only restriction is that there be a one-to-one correspondence between each item and each number. The code number for a given item is then recorded on the table forms for each of the key concepts associated with or imputed to this item. For a manual system the code numbers are generally arranged in an ascending order for each key concept; typically, larger numbers are assigned as the system grows. A separate reference file is maintained which relates each code number to its item. When the items being organized are literature articles in some scientific field, for example, the reference file might consist of another set of index cards, arranged in ascending numerical order with one code number per card, with such pertinent information as author(s), affiliation, source, abstract and the

key concepts themselves. One could also have a file of the articles themselves, also arranged in ascending order of the code numbers.

SCANNING OPERATION

THE SYSTEM THEN operates as follows for the retrieval of specific items. The table forms or index cards for each key concept of interest in a given search are scanned and all code numbers which appear on all such table forms are stored or recorded. The code numbers resulting from this scanning operation are then used to locate the corresponding items (journal articles, abstracts, etc) in the reference file. In very sophisticated systems, additional letter or numerical codes may be assigned to each key concept. The purpose of these additional codes is to denote the role of each key concept. Thus, these codes may be used to denote whether the key concept serves as an input, output, environmental factor, active concept, passive concept, means, etc. These role codes can then be linked to establish a very specific search of a large system. In this case, a given key concept may require a number of separate table forms, one for each role code assigned to that word. In a relatively simple system such as the one described in this article, such sophistication is not necessary and was not employed.

The list of key concepts selected for this reaction engineering application is given in Table 1. It is not pretended that this list would serve as an all-inclusive one for the entire reaction engineering field. Within an educational environment, however, it is felt that this list is quite representative of the key concepts covered in a typical undergraduate course in chemical reaction engineering. The reference file for this problem organization system would relate each code number to a specific problem or the source thereof. In the search operation, code numbers would, as before, be obtained by scanning and recording the matches. A specific example of this search procedure will be given later.

The selection of the key concepts themselves is naturally somewhat subjective. A given person may attach various subtle interpretations to certain key concepts. Hence, amplification of some of the entries in Table 1 would perhaps be useful. For example, numerical integration is intended to refer to problems in which analytical integration of the governing differential equations is not possible, and would thus also embrace graphical and other manual methods of integration. The nonisothermal entry is intended to also include series of reactors operated at different but perhaps constant temperatures. A key concept such as activation energy, half-life, residence time or selectivity is associated with a given problem only when that concept is felt to be an integral part of the solution procedure to that problem.

The items to be organized in this system are problems in the area of reaction engineering from various sources such as textbooks, manuals and journal articles. The problems from textbooks can be either solved example problems or unsolved ones such as appear at the ends of various chapters. For brevity of presentation purposes in this article, the number of organized problems has been restricted to several hundred, but the extension of this system to any number of entries should be readily apparent.

Copies of the table forms for this system are shown in Table 2. This particular type of form, with a vertical arrangement into ten columns headed by the digits 0-9, is a very popular one. The code number for a given item is listed in one of these columns, depending upon its last digit. Within a given column, the code numbers are listed vertically in ascending order. This particular arrangement of the code numbers on a table form

TABLE 1
List of Key Concepts in the System for Organization of Reaction Engineering Problems.

Activation Energy	Mechanism
Autocatalytic	Multiple Reactors
Batch Reactor	Non-Isothermal
Catalytic	Numerical Integration
Competitive	Residence Time
Consecutive	Reversible
CSTR	Second-Order
Equilibrium	Selectivity
First-Order	Semi-Batch Reactor
Fractional Order	Tubular Reactor
Half Life	Unknown Order
Heterogeneous	Zero-Order

greatly facilitates the search procedure. The code numbers for individual reaction engineering problems beginning with unity, are assigned in ascending order as the number of entries increases and are recorded manually on the appropriate table forms.

The reference file for this system is presented in Table 3. A shortcut, mnemonic method for identifying sources has been employed here. This method, although somewhat arbitrary, has proven

TABLE 2

MECHANISM

0	1	2	3	4	5	6	7	8	9
120	121	52	53	94	5	46	47		129
250	251	122	93	124	125				249
		252	123	254					
			253						

MULTIPLE REACTORS

0	1	2	3	4	5	6	7	8	9
10	11	102	103	34	95	36	77	178	9
40	181	182	173	174	165	96	97	198	79
100	271	232	183		175	176	177		99
180					255		187		119
							197		
							257		

NON-ISOTHERMAL

0	1	2	3	4	5	6	7	8	9
20	111	112	113	14	15	16	17	8	109
110	231				65	106	107	28	119
230					275	116	117	108	
						216		118	

NUMERICAL INTEGRATION

0	1	2	3	4	5	6	7	8	9
20	81	112	113	14	15	16	17	18	
150	91		163	74	75	106	107	28	
	111			84	105	156	277		
	231			104	155	216			
					175				
					275				

ACTIVATION ENERGY

0	1	2	3	4	5	6	7	8	9
220	1	222	43	244	275	126	127	8	169
	21	272	83	274				58	219
	111		273					128	269
	221							148	
								168	
								218	

AUTOCATALYTIC

0	1	2	3	4	5	6	7	8	9
		262	263		175	6			

BATCH REACTOR

0	1	2	3	4	5	6	7	8	9
30	21	12	23	24	15	26	7	28	19
50	51	22	83	44	25	56	27	48	29
60	61	32	133	54	55	86	57	88	49
70	71	52	143	84	85	106	87	138	59
130	111	62	223	134	135	146	137	148	139
140	131	82	243	144	145	206	147	188	229
190	201	112		154	155	226	167	228	239
210	241	132		224	215	236	217	238	279
230	281	142		234	225	246	227	248	
280		242		244	235		237	278	
					245		247		
							277		

CATALYTIC

0	1	2	3	4	5	6	7	8	9
70	71	282	3	14	5	276		68	49
				264					69
									89

RESIDENCE TIME

0	1	2	3	4	5	6	7	8	9
80	91	12	93	94	95	76	67	68	19
90	171	102	153	154	175	96	77	78	69
150	181	182	163	164	185	166	97	98	79
	211	212	173			176	167	118	99
			183			186	177	178	169
			273			256	187	198	
							197		
							257		

REVERSIBLE

0	1	2	3	4	5	6	7	8	9
30	31	152	13	44	25	216	7	38	49
90	51	282		104	35	276	37	48	119
140	71				75		137	88	149
	81				255			118	229
	231							138	
	271							248	
								278	

SECOND-ORDER

0	1	2	3	4	5	6	7	8	9
10	71	2	73	44	15	36	7	8	9
70	81	12	83	64	45	46	27	18	29
90	91	22	93	74	75	116	107	38	49
170	111	42	113	94	105	146	207	48	59
210	171	62	193	104	115	166	237	58	89
230	231	72	203	114	135	176	247	88	99
280		82	263	174	165	196	277	98	149
		92		184	185	206		108	159
		152		194	195	246		188	259
		192		204	205			198	279
		202		214	255				
		232			265				
		262							
		272							

SELECTIVITY

0	1	2	3	4	5	6	7	8	9
30	61	62	33	94	45	26	27	18	19
60	91	192	93	114	95	116	107	78	59
100	191	202	113	194	115	196	197	98	99
200	201	212	193	204	195	206	207	108	199
280	211		203	214	205	256		198	279
			213					208	

COMPETITIVE

0	1	2	3	4	5	6	7	8	9
30	91	62	63	64	75	116	107	18	59
60	141	192	93	194	195	196	197	98	99
200	191	202	113	204	205	206	207	108	199
210	201	212	193	214	245	246	247	198	279
	211		203				277	278	
	281		213						

CONSECUTIVE

0	1	2	3	4	5	6	7	8	9
30	51	212	13	114	35	26	27	78	19
100	61		33		45	196	277	98	59
210	91		93		75	256		208	99
280	211		193		95			238	209
	281				115			278	279
					195				

CSTR

0	1	2	3	4	5	6	7	8	9
10	11	2	33	4	15	36	37	18	9
40	101	32	93	14	35	66	77	78	19
100	161	102	163	34	95	76	97	98	39
170	171	162	183	94	115	96	117	108	79
180	181	172	193	154	175	116	157	158	99
190	191	182	203	164	195	166	177	168	109
200	201	192	213	174	205	176	187	178	119
	261	202		184	255	196	197	198	149
		212		204	265	256	207	208	159
		232		214			257	258	169
		262		234					179
				264					189
									199

EQUILIBRIUM

0	1	2	3	4	5	6	7	8	9
90	51		13	44	25		7	38	49
140	71			74	75		57	48	119
	271				215		137	88	229
					255			118	
								138	
								248	

SEMI-BATCH REACTOR

0	1	2	3	4	5	6	7	8	9
80	31		103	104	45				259
110	81				105				
260	261				265				

TUBULAR REACTOR

0	1	2	3	4	5	6	7	8	9
20	41	12	3	4	65	16	17	18	39
40	91	42	13	14	75	156	67	38	69
90	151	72	73	64	95	176	107	68	79
150	171	92	93	74	165	186	167	78	89
160	181	152	113	114	175	196	267	118	159
170	191	192	153	154	185	216		208	199
270	201	202	163	184	195	266		268	269
	211	212	173	234	275	276			
	271	262	193	274					
		272	203						
		282	233						
			263						
			273						

UNKNOWN ORDER

0	1	2	3	4	5	6	7	8	9
140	21	52	23	74	135	226	47	68	69
	161	92	73	164	225		67	138	169
		142	183	224			147	148	
		162	223				227	168	
		182						228	

ZERO-ORDER

0	1	2	3	4	5	6	7	8	9
			143	144			217		209
			203	234					

FIRST-ORDER

0	1	2	3	4	5	6	7	8	9
10	11	32	3	4	25	16	17	28	9
20	31	92	33	14	35	26	27	38	19
30	41	102	43	24	55	76	37	48	39
40	51	112	53	34	85	86	57	78	79
50	61	132	73	54	95	96	77	118	109
60	91	152	93	74	115	106	87	178	119
80	101	192	103	84	145	136	97	198	179
100	111	202	203	94	195	186	117	208	189
160	121	212	213	114	245	196	137	238	209
180	131	242	233	134	275	216	177	248	229
190	141		243	194		236	187	258	239
260	151		273	244		256	197	268	269
270	181			274		266	257	278	
	211								
	241								
	261								
	271								
	281								

FRACTIONAL ORDER

0	1	2	3	4	5	6	7	8	9
150	191	252	133		235		47		249
240	251		253						

HALF-LIFE

0	1	2	3	4	5	6	7	8	9
180	241	52	223	24	225	56		148	139
240					235				

HETEROGENEOUS

0	1	2	3	4	5	6	7	8	9
		282	3	264	5	276	257	68	69
			63				267	98	99
								268	259

to be very useful and is based in part upon authors' initials or the first letters of multiple authors' last names. Thus, for example SMW refers to the text by S.M. Walas, JMS2 refers to the second edition of the text by J.M. Smith, and C&J refers to the text by A. R. Cooper and G. V. Jeffreys. The numbers following the author letter codes denote the location within a given text. Again, for example, 3-4 refers to problem 4 at the end of Chapter 3, while 157X refers to an example problem which appears on page 157. A complete directory of the mnemonic codes is provided in Table 4.

THE USAGE OF this system for locating problems involving specific concepts will be illustrated by two examples. Suppose one is interested in re-

TABLE 3. Reference File Code Numbers and Sources of Reaction Engineering Problems.

Code No.	Problem Source	Code No.	Problem Source	Code No.	Problem Source	Code No.	Problem Source	Code No.	Problem Source	Code No.	Problem Source
1	MB 1-4.1	48	JMS2 2-9	95	JMS2 4-14	142	OL2 3-19	189	OL2 6-21	236	WSL 2-12
2	MB 1-6.2	49	JMS2 2-10	96	JMS2 4-15	143	OL2 3-23	190	OL2 6-23	237	MS&R2 3-4
3	MB 1-7.2	50	JMS2 2-11	97	JMS2 4-16	144	OL2 3-24	191	OL2 170X	238	HBP 2-20
4	MB 1-8.2	51	JMS2 2-12	98	JMS2 4-17	145	OL2 3-25	192	OL2 172X	239	CL&W 3-21
5	MB 3-3.2	52	JMS2 2-13	99	JMS2 4-18	146	OL2 3-26	193	OL2 194X	240	P&L 22X
6	MB 6-1.1	53	JMS2 2-14	100	JMS2 4-19	147	OL2 3-27	194	OL2 7-3	241	AIChE 1K
7	SWC 13-5	54	JMS2 2-17	101	JMS2 4-20	148	OL2 3-29	195	OL2 7-5	242	AIChE 4K
8	SWC 13-30	55	JMS2 2-18	102	JMS2 4-21	149	OL2 106X	196	OL2 7-6	243	AIChE 6K
9	SWC 15-7	56	JMS2 2-19	103	JMS2 4-22	150	OL2 111X	197	OL2 7-7	244	AIChE 7K
10	SWC 15-8	57	JMS2 2-20	104	JMS2 4-23	151	OL2 113X	198	OL2 7-8	245	AIChE 24K
11	SWC 15-9	58	JMS2 2-21	105	JMS2 4-24	152	OL2 114X	199	OL2 7-9	246	AIChE 26K
12	SWC 466X	59	JMS2 2-22	106	JMS2 207X	153	OL2 5-1	200	OL2 7-10	247	AIChE 27K
13	SWC 19-8	60	JMS2 2-23	107	JMS2 214X	154	OL2 5-2	201	OL2 7-11	248	AIChE 31K
14	SWC 19-11	61	JMS2 2-24	108	JMS2 228X	155	OL2 5-3	202	OL3 7-12	249	SMW 46X
15	SWC 19-20	62	JMS2 2-25	109	JMS2 234X	156	OL2 5-4	203	OL2 7-13	250	SMW 2-18
16	SWC 19-26	63	JMS2 3-1	110	JMS2 237X	157	OL2 5-5	204	OL2 7-15	251	SMW 2-19
17	SWC 12-27	64	JMS2 3-2	111	JMS2 5-1	158	OL2 5-6	205	OL2 7-16	252	HSF 265X
18	SWC 19-30	65	JMS2 3-3	112	JMS2 5-2	159	OL2 5-7	206	OL2 7-17	253	SWB 50X
19	SWC 19-32	66	JMS2 3-4	113	JMS2 5-3	160	OL2 5-8	207	OL2 7-19	254	KJL1 84X
20	SWC 19-33	67	JMS2 3-5	114	JMS2 5-4	161	OL2 5-9	208	OL2 7-21	255	SMW 86X
21	C&J 3-2	68	JMS2 3-6	115	JMS2 5-5	162	OL2 5-10	209	OL2 7-22	256	SMW 92X
22	C&J 3-3	69	JMS2 3-7	116	JMS2 5-6	163	OL2 5-11	210	OL2 7-23	257	SMW 4-7
23	C&J 3-4	70	JMS2 132X	117	JMS2 5-7	164	OL2 5-12	211	OL2 7-25	258	HSF 111X
24	C&J 3-8	71	JMS2 134X	118	JMS2 5-8	165	OL2 5-13	212	OL2 7-26	259	SMW 120X
25	C&J 3-11	72	JMS2 138X	119	JMS2 5-9	166	OL2 5-14	213	OL2 7-29	260	SMW 5-17
26	C&J 3-13	73	JMS2 142X	120	OL2 19X	167	OL2 5-15	214	OL2 7-31	261	D&T 4-2
27	C&J 3-14	74	JMS2 145X	121	OL2 2-6	168	OL2 5-17	215	OL2 8-1	262	D&T 4-8
28	C&J 133X	75	JMS2 157X	122	OL2 2-7	169	OL2 5-19	216	OL2 8-11	263	D&T 4-9
29	C&J 4-2	76	JMS2 167X	123	OL2 2-9	170	OL2 5-21	217	OL2 12-15	264	HSF 209X
30	C&J 4-3	77	JMS2 172X	124	OL2 2-10	171	OL2 129X	218	SMW 1-6	265	MS&R2 3-7
31	C&J 4-5	78	JMS2 180X	125	OL2 2-11	172	OL2 130X	219	SMW 1-7	266	SMW 105X
32	C&J 150X	79	JMS2 182X	126	OL2 2-13	173	OL2 134X	220	SMW 1-8	267	SMW 5-13
33	C&J 5-3	80	JMS2 186X	127	OL2 2-15	174	OL2 138X	221	SMW 1-9	268	SMW 5-14
34	C&J 5-1	81	JMS2 189X	128	OL2 2-16	175	OL2 153X	222	SMW 1-10	269	D&T 3-7
35	C&J 5-4	82	JMS2 4-1	129	OL2 2-17	176	OL2 6-1	223	SMW 36X	270	HSF 115X
36	C&J 5-7	83	JMS2 4-2	130	OL2 78X	177	OL2 6-2	224	SMW 42X	271	HSF 4-8
37	C&J 5-10	84	JMS2 4-3	131	OL2 3-2	178	OL2 6-3	225	SMW 2-3	272	WSL 2-9
38	C&J 215X	85	JMS2 4-4	132	OL2 3-3	179	OL2 6-4	226	SMW 2-4	273	AIChE 33K
39	C&J 6-1	86	JMS2 4-5	133	OL2 3-4	180	OL2 6-5	227	SMW 2-5	274	AIChE 34K
40	C&J 6-2	87	JMS2 4-6	134	OL2 3-5	181	OL2 6-7	228	SMW 2-7	275	CEE 116X
41	C&J 6-4	88	JMS2 4-7	135	OL2 3-6	182	OL2 6-9	229	SMW 2-10	276	SMW 7-12
42	C&J 6-6	89	JMS2 4-8	136	OL2 3-7	183	OL2 6-10	230	SMW 76X	277	CACHE 1X
43	JMS2 41X	90	JMS2 4-9	137	OL2 3-9	184	OL2 6-11	231	SMW 3-7	278	F&P 160X
44	JMS2 66X	91	JMS2 4-10	138	OL2 3-11	185	OL2 6-13	232	SMW 4-12	279	SWB 45X
45	JMS2 79X	92	JMS2 4-11	139	OL2 3-12	186	OL2 6-15	233	SMW 5-1	280	SMW 49X
46	JMS2 2-2	93	JMS2 4-12	140	OL2 3-13	187	OL2 6-17	234	HSF 4-2	281	SMW 2-23
47	JMS2 2-3	94	JMS2 4-13	141	OL2 3-15	188	OL2 6-19	25	SWB 1	282	SMW 7-2

action engineering problems having to do with consecutive, competitive, second-order reactions occurring in a CSTR. A scanning search of the table forms for each of the four key concepts associated with this class of problems discloses that the following code numbers appear on each of these forms: 93, 193, 195, 196, 98, 99. Similarly, a search for problems involving reaction mechanisms leading to fractional reaction orders yields the following entries common to each of the two pertinent table forms: 251, 252, 253, 47, 249. Some suggestions regarding the usage of these forms are presented below.

Large numbers of organized items (problems) necessarily appear on the table forms for the more general key concepts, such as first-order, second-order, batch, tubular and CSTR. In a given search involving several key concepts then, one is well advised to first scan the table forms for the more specialized pertinent concepts, e.g., autocatalytic, half-mile, multiple reactors, and then to proceed to the more general concepts. This sequence prevents the initial accumulation of a large number of item code numbers which would later have to be discarded.

This article has described the usage of the key concept method of information organization and retrieval for setting up and organizing a

TABLE 4
Directory of Mnemonic Codes for Identifying Sources of Reaction Engineering Problems.

CODE	SOURCE
AIChE	"Chemical Engineering Problems," American Institute of Chemical Engineers," New York (1956) (K suffixed to associated numerical codes refers to the problem set on reaction kinetics).
CACHE	"Computer Programs for Chemical Engineering Education," Vol. II (Kinetics), Edited by M. J. Reilly, Aztec Publishing Co., Austin, Texas (1972).
CEE	Briggs, D. E., Carnahan, B. and Williams, G. B., "The Use of Computers in Chemical Engineering Education," The University of Michigan. Ann Arbor, Mich. (1963).
CL&W	Carnahan, B., Luther, H. A. and Wilkes, J. O., "Applied Numerical Methods," Wiley, New York (1969).
C&J	Cooper, A. R. and Jeffreys, G. V., "Chemical Kinetics and Reactor Design," Prentice-Hall, Englewood Cliffs, N.J. (1973).
D&T	Denbigh, F., and Turner, J.C.R., "Chemical Reactor Theory," 2nd Edition, University Press, Cambridge (1971).
F&P	Frost, A. A. and Pearson, R. G., "Kinetics and Mechanism," Wiley, New York (1953).
HBP	Phillips, H. B., "Differential Equations," 3rd Edition, Wiley, New York (1934).
HSF	Fogler, H. S., "The Elements of Chemical Kinetics and Reactor Calculations," Prentice-Hall, Englewood Cliffs, N.J. (1974).
JMS2	Smith, J. M., "Chemical Engineering Kinetics," 2nd Edition, McGraw-Hall, New York (1970).
KJL1	Laidler, K. J., "Chemical Kinetics," 1st Edition, McGraw-Hill, New York (1950).
MB	Boudart, M., "Kinetics of Chemical Processes," Prentice-Hall Inc., Englewood Cliffs, N.J. (1968).
MS&R2	Mickley, H. S., Sherwood, T. K. and Reed, C. E., "Applied Mathematics in Chemical Engineering," 2nd Edition, McGraw-Hill, New York (1957).
OL2	Levenspiel, O., "Chemical Reaction Engineering," 2nd Edition, Wiley, New York (1972).
P&L	Panchenkov, G. M. and Lebedev, V. P., "Khimicheskaya Kinetika i Kataliz," University of Moscow Press, Moscow (1961).
SMW	Walas, S. M., "Reaction Kinetics for Chemical Engineers," McGraw-Hill, New York (1959).
SWB	Benson, S. W., "The Foundations of Chemical Kinetics," McGraw-Hill, New York (1960).
SWC	Churchill, S. W., "The Interpretation and Use of Rate Data: The Rate Concept," McGraw-Hill, New York (1974).
WSL	LaLonde, W. S., "Professional Engineer's Examination Questions and Answers," 2nd Edition, McGraw-Hill, New York (1960).

file of reaction engineering problems. This file, which has been organized and maintained by manual methods with no great effort, has been found to be very useful in an educational environment. It should be obvious, moreover, that these same methods should be amenable to other instructional areas of chemical engineering. Thus, one should be easily able to construct similar files, if one is interested, for such areas as thermodynamics, unit operations and process control, to name a few. □

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than precise. Professor Astarita attempts to explain the *methods* in a setting which anticipates the heavy technical needs of the final chapters on fading memory, a strategy which I think taints his exposition of fundamentals with a vagueness impossible to avoid in such an ambitious undertaking.

For example, I believe Chapter 4 is seriously flawed by its opening section which, in anticipation of Chapter 5, deals with differentiability of functionals with respect to present values of temperature. This discussion is too vague to be of much use, plays no real role in the balance of the chapter, and is likely to detract from the effectiveness of the pedagogically critical sections immediately following. I wish Professor Astarita had chosen to divorce his exposition of methodology from his skillful, but necessarily sketchy, description of Coleman's work on fading memory.

I wish also that literature citations had been heavier so that readers could more readily make contact with the original literature—indeed, the crucial Coleman-Noll paper of 1963 is not cited at all.

Despite these remarks, let me state once again that the book is an important one for academic chemical engineers and might substantially influence the way we think about thermodynamics. It deserves reading, as do the source papers and the monographs by Truesdell and Day. Professor Astarita has reached beyond our own literature and brought to it something of value.

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