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A manual on water desalination: economics,appendices

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9. ABSTRACT

(Engineering--Hydraulics R&D)
Volumes I & II; Supplements to Volumes I & II
A PROJECT: Intended to guide the officers of the Agency for International Development in evaluating and determining the technical and economic feasibility of desalination projects for which U.S. Government assistance may be sought. The original two-volume Manual -- one volume on technology and one on economics -- was prepared by Kaiser Engineers of Oakland, California in April, 1967. In October, 1972, Burns and Roe Inc., of Oradell, New Jersey produced a supplement to each volume.
Duration: 1967: 1972
DEVELOPMENTS: Technical improvements and cost reductions of desalination have added a new dimension to water supply planning: This method of supplementing freshwater supplies demands prominent consideration as a means of meeting future water needs. The Manual reviews various desalination processes and presents economic and technical guidelines for gathering and analyzing data on energy and water resources and requirements -- data that must be considered in deciding whether water desalination is a viable solution to an area's water shortage problem. Volume I discusses eight desalination methods and describes a typical plant for each: Distillation processes - 1. vertical falling and rising film, 2. multistage flash, 3. multieffect multistage flash, 4. vapor compressions, and 5. solar stills; Non-distillation processes - 6. vacuum-freezing vapor-compressions, 7. electrodialysis, and 8. reverse osmosis. It includes a feasibility study on combining desalination

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plants with electric power generating plants, and a discussion on combining desalination with production of chemical by-products. Volume II gives guidelines for studies to determine if desalination is the optimum solution to an area's water shortage problem. An Appendix lists existing plants, technical data on properties of seawater and brackish water, and sample survey questionnaires. The Supplements to Volumes I & II do not present new technologies but rather refinement and commercialization of the material in the two volumes. They update technical and economic guides - often pointing to the increased viability of desalination solutions. The Supplements describe typical plants built since 1967 and provide sections on conceptual designs, water development planning, and updated budget water plant pricing. They add as well some environmental considerations, and feed treatment and brine disposal methods. Whereas the Manual provides information for evaluation and determination of the feasibility of desalination programs, it does not provide the detailed technical data required by a desalination plant designer. Volumes I & II can be used independently of each other; the Supplements, however, do require reference to Volumes I & II.

A MANUAL ON WATER DESALINATION

VOLUME TWO — ECONOMICS:

APPENDICES

APRIL 1967

PREPARED FOR

Department of State
AGENCY FOR INTERNATIONAL DEVELOPMENT
OFFICE OF ENGINEERING
Washington, D.C. 20523

KAISER ENGINEERS OAKLAND CALIFORNIA

A MANUAL ON WATER DESALINATION

VOLUME TWO

Prepared For

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Notice

"This manual was prepared for the Agency for International Development (AID), to guide its officers in evaluating and determining the technical and economic feasibilities of desalination programs and projects, for which United States Government assistance may be furnished or sought. The information contained herein is not sufficient for and is not intended to be the sole basis for design or construction of a project at any particular location, or as a substitute for professional judgment, advice, and design work by competent engineers in connection with such a project."

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APPENDIX A

LIST OF WATER DESALINATION PLANTS

(Excluding distillation plants with less than 100,000 gpd capacity)

STATUS LEGEND

C - Under Construction

O - Operating

X - Shut Down

Long Tube Vertical

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Argentina	San Nicolas	2	190	O	Atlas-Werek, (W. Germany)	1
England	Cheshire	2	173	O	Aiton & Co. (England)	1
England	Tilbury, Essex-B	4	634	C	Aiton & Co. (England)	1
England	West Thur-rock, Essex-B	3	388.5	O	Aiton & Co. (England	1
Germany, West	Farge	1	127	O	Atlas-Werke (W. Germany)	1 1
Germany, West	Goldenberg	1	146	O	Atlas-Werke (W. Germany)	1
Germany, West	Hagen	2	152	O	Atlas-Werke (W. Germany)	1
Germany, West	Helmstedt	2	292	O	Atlas-Werke (W. Germany)	1
Germany, West	Neumunster	1	120	O	Atlas-Werke (W. Germany)	1
Germany, West	Offleben	2	152	O	Atlas-Werke (W. Germany)	1
Germany, West	Stuttgart	1	331	O	Atlas-Werke (W. Germany)	1
Germany, West	Weisweiler	1	101	O	Atlas-Werke (W. Germany)	1
Korea, South	Yung Wol	2	127	O	Atlas-Werke (W. Germany)	1
U.S., Texas	Freeport	1	1,000	O	Chicago Bridge & Iron	1
USSR, Kazakh	Shevchenko	-	1,300	O	USSR Govt	1

Flash Distillation

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Antigua (British)	W. Indies Oil Co	1	150	C	Aqua-Chem, Inc.	1
Bermuda (British) W. Indies	Kindley AFB:A	1	100	O	Aqua-Chem, Inc.	1
Canary Islands (Spain)	Lanzorota	1	650	C	Westinghouse	1
Cyprus	Dekhelia	2	400	O	Buckley & Taylor(England)	1
Ecuador	Ancon	1	120	C	Aiton & Co (England)	1
Gibraltar (British)	NATO	2	145	O	Aqua-Chem, Inc.	1
Kuwait	Getty Oil Co	1	100	O	Aqua-Chem, Inc.	1
Kuwait	Shuaiba: (Govt) B	1	2,400	C	Westinghouse	1
Kuwait	Shuaiba: (Govt) C	-	150	C	Aqua-Chem, Inc.	1
Kuwait	Shuwaikh: (Govt) G	2	4,800	C	Westinghouse	1
Libya	Port Brega: A	2	400	C	Aqua-Chem, Inc.	1
Libya	Port Brega: B	2	200	O	Aqua-Chem, Inc.	1
Libya	Zlitan	2	100	O	Westinghouse	1
Mexico	Tijuana	3	189.9	O	Westinghouse	1
Saudi Arabia	Ras Tanura: A	1	700	O	---	1
U.A.R. (Egypt)	Belayim	-	158	O	Westinghouse	1
U.S., California	PG&E-Contra Costa No. 6	1	104.5	O	Westinghouse	7
	PG&E-Contra Costa No. 7	1	104.5	O	Westinghouse	7
	PG&E-Morro Bay No. 3	1	123	O	Westinghouse	7

Flash Distillation (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
U.S. California	PG&E-Morro Bay No. 4	1	123	O	Westinghouse	7
	PG&E-Moss Landing No. 6	1	188	O	Westinghouse	7
	PG&E-Moss Landing No. 7	1	183	O	Westinghouse	7
	San Onofre	2	172.5	C	Westinghouse	1
Johnson Island	AEC	1	150	O	Aqua-Chem, Inc	1
Kentucky	Big Sandy No. 1	1	116.5	O	Westinghouse	1, 9
Louisiana	Freeport	2	120	O	Baldwin-Lima-Hamilton	1, 8
Massachusetts	Brayton Point: A-No. 1	1	111	O	Westinghouse	1, 9
Massachusetts	Brayton Point: B-No. 2	1	111	O	Westinghouse	1, 9
Pennsylvania	Philadelphia: A	1	144	O	Westinghouse	1
Pennsylvania	Philadelphia: B	1	100	O	Westinghouse	1
Tennessee	TVA: A-Paradise No. 1	1	209	O	Westinghouse	1, 9
	TVA: B-Paradise No. 2	1	209	O	Westinghouse	1, 9
	TVA: C-Bull Run No. 1	1	169	O	Westinghouse	1, 9
Texas	Handley No. 3	1	144	O	Westinghouse	1, 9
Virginia	Possum Point: C-No. 4	1	187	O	Westinghouse	1, 9
Wake Is.	CAA	2	100	O	Aqua-Chem, Inc	1

Flash Distillation (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
W. Virginia	Mt. Storm: No. 1	1	328	O	Westinghouse	9
W. Virginia	Mt. Storm: No. 2	1	328	C	Westinghouse	9
Venezuela	(Port)Cardon	1	1,440	O	Buckley & Taylor (England)	1

Multistage Flash

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref.
Aruba (Nether-lands Antilles)	Balashi	1	800	O	Aqua-Chem, Inc	1
Bahamas (British)	Nassau, New Prov. Island	2	1,440	O	Weir Westgarth (England)	1 1
Bermuda (British) W. Indies	King Edward VII Hospital	1	156	O	Aqua-Chem, Inc	1
Bonaire Is. (Nether-lands Antilles)	W. Indies	1	134	O	Weir Westgarth (England)	1
Ceuta (Spanish Morocco)	---	2	1,055	O	Atlas-Werke (W. Germany)	1
Channel Is. (British)	Guernsey	1	600	O	Weir Westgarth (England)	1
Chile	Chanaral	1	264	O	Weir Westgarth (England)	1
Chile	---	1	145	O	Aqua-Chem, Inc	10
Cuba	Guantanamo	3	2,250	O	Westinghouse	1
Curacao (Nether-lands Antilles)	Mundo Nobo: B	2	3,440	O	Weir Westgarth (England)	1
Curacao	Mundo Nobo: -	1	1,584	O	Weir Westgarth (England)	1
England	Scunthrop (Lysaught)	3	432	-	Weir Westgarth (England)	1
England	Scunthrop (RTB)	2	288	-	Weir Westgarth (England)	1
Germany, West	Bremen	1	132	C	Atlas-Werke (W. Germany)	1
Iran	Imah Hassan	1	158	O	Weir Westgarth (England)	1

Multistage Flash (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Iran	Khark, Is.	2	300	O	Weir Westgarth (England)	1
Iran	Khark, Is.:B	1	300	C	Weir Westgarth (England)	1
Israel	Eilat: A	1	1,000	O	Baldwin-Lima-Hamilton	1
Italy	Carbo Sarda	1	266	O	Aqua-Chem, Inc	8
Italy	Snam Pro-getti	2	316	O	Weir Westgarth (England)	8
Italy	Taranto: A	2	1,200	O	Aqua-Chem, Inc	1
Italy	Taranto: B	3	600	C	Aqua-Chem, Inc	1
Japan	Kyushu	1	700	O	Ishikawajima-Harima (Japan)	1
Kuwait	Khafji (Neutral Zone) A	1	500	O	Ishikawajima-Harima (Japan)	1
Kuwait	Khafji (Neutral Zone) B	1	500	O	Westinghouse	1, 9
Kuwait	Minhal Ahmadi (Kuwait Oil Co): A	1	720	O	Weir Westgarth (England)	1
Kuwait	Minhal Ahmadi: B	1	360	O	Weir Westgarth (England)	1
Kuwait	Minhal Ahmadi: C	1	720	O	Weir Westgarth (England)	1
Kuwait	Shuaiba: (Govt) A	5	6,000	O	Weir Westgarth (England)	1
Kuwait	Shuwaikh (Govt) C	4	2,520	O	Westinghouse	1
Kuwait	Shuwaikh: (Govt) D	2	2,400	O	Weir Westgarth (England)	1
Malta	Valetta	1	1,200	C	Aqua-Chem, Inc	1
Nether-lands	Pernis	1	762	O	Weir Westgarth (England)	1

Multistage Flash (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Peru	Ilo	1	720	C	Aqua-Chem, Inc	1, 9
Qatar	Doha:A	2	1,800	O	Weir Westgarth (England)	
Qatar	Doha:B	2	360	O	Weir Westgarth (England)	
SW Africa	Ludertiz	1	144	O	Weir Westgarth (England)	
UAR (Egypt)	Abut Zenima (Sinai)	1	600	O	Weir Westgarth (England)	
US: California	Catalina Is. (formerly Oxnard-Mandalay)	1	144	O	Aqua-Chem, Inc	
California	Oxnard-Mandalay Steam Station	1	100	-	Aqua-Chem, Inc	8
	Point Loma-OSW 2 (moved to Guantanamo, Cuba)	1	1,250	-	Westinghouse	6, 8
Florida	Key West	1	2,620	C	Westinghouse	1
Gulf of Mexico	---	1	200	O	Aqua-Chem, Inc	10
Louisiana	Gulf Oil	1	216	O	Foster-Wheeler	8
New York	Rochester:A	1	136	O	Struthers Scientific	1
Pennsylvania	Philadelphia: C	1	115	O	Struthers Scientific	1
Pennsylvania	US Steel	1	1,000	O	Westinghouse	9
Rhode Is.	Newport	1	115	O	Struthers Scientific	1
Texas	Chocolate Bayou	1	905	O	Westinghouse	1
Texas	Dow Chemical	1	216	O	Westinghouse	9

Multistage Flash (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Texas	Sweeney	1	132.5	O	Struthers Scientific	1
Texas	Union Carbide	2	4,320	O	Westinghouse	9
Virgin Is.	St. Croix	1	1,500	O	Westinghouse	1
Virgin Is.	St. Croix-Hess Oil	1	172	O	Westinghouse	9
Virgin Is.	St. Thomas: Charlotte Amalie	1	1,000	O	Westinghouse	1
Virgin Is.	St. Thomas: Charlotte Amalie	1	315	O	Aqua-Chem, Inc	1

Submerged Tube

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Aden (British)	Aden	3	485	O	Weir Westgarth (England)	1
Aden (British)		1	400	-	British	8
Argentina	Buenos Aires Delul SA	1	150	-	Escher Wyss (Switzerland)	8
Aruba	Aruba Standard Oil	4	254	O	Baldwin-Lima-Hamilton	1
Aruba (Netherlands Antilles)	Balashi	5	2,688	O	Weir Westgarth (England)	1
Aruba	Balashi	10	806	O	Weir Westgarth (England)	1
Aruba	Balashi	5	310	O	Baldwin-Lima-Hamilton	1
Aruba	--	6	318	-	Weir Westgarth (England)	8
Bahamas (British)	--	2	1,200	X	Weir Westgarth (England)	8
Brazil	Mundo Nobo	-	357	-	---	1
Brazil	Sao Paulo	2	200	-	---	1
Curacao (Netherlands Antilles)	--	1	1,000	-	Weir Westgarth (England)	8
Curacao (Netherlands Antilles)	--	6	318	-	Weir Westgarth (England)	8
Curacao	Mundo Nobo: A	2	1,074	O	Weir Westgarth (England)	1
Curacao	Mundo Nobo: B	2	161	O	Weir Westgarth (England)	1
Curacao (Netherlands Antilles)	Penstraat	12	967	O	Weir Westgarth (England)	1

Submerged Tube (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
England	Acton Lane	1	173	-	Weir Westgarth (England)	1
England	Barking	1	202	-	Weir Westgarth (England)	1
England	Battersea Power Sta. "B"	1	139	-	Weir Westgarth (England)	1
England	Belfast Corp	1	144	-	Weir Westgarth (England)	1
England	Clarence Dock	1	144	-	Weir Westgarth (England)	1
England	Deptford East Power Sta	1	139	-	Weir Westgarth (England)	1
England	Dunston Power Sta	1	144	-	Weir Westgarth (England)	1
England	Fulham	1	106.4	-	Weir Westgarth (England)	1
England	Mersey Mill	1	173	-	Weir Westgarth (England)	1
England	Sketon Grange	1	173	-	Weir Westgarth (England)	1
England	S. Denes, Gt Yarmouth: A	3	181.5	O	Aiton & Co (England)	1
England	Thames Mill	1	173	-	Weir Westgarth (England)	1
England	Tilbury, Essex: A	8	242	O	Aiton & Co (England)	1
England	Willington	1	144	-	Weir Westgarth (England)	1
Gilbraltar (British)	The Admi-ralty: A	2	161	O	Weir Westgarth (England)	1
Iran	---	3	129.6	O	Aiton & Co (England)	1
Israel	Dead Sea	2	260	O	Baldwin-Lima-Hamilton	1
Israel	Sedom	-	250	O	---	1

Submerged Tube (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Italy	Miraflori	1	300	O	Escher Wyss (Switzerland)	1
Kuwait	(Kuwait Oil Co)	6	720	-	Westinghouse	8
Kuwait	Shuwaikh (Govt) A	10	1,200	O	Westinghouse	1
Kuwait	Shuwaikh, Kuwait (Govt) Plant B	10	1,200	-	Weir Westgarth (England)	8
Mexico	San Luis Potosi	1	120	O	Baldwin-Lima-Hamilton	1
Peru	Labitos: B	1	134	O	Weir Westgarth (England)	1
Qatar	Doha: B	6	240	O	---	1
Saudi Arabia	Ras Tanura: B	4	160	O	Baldwin-Lima-Hamilton	1
Saudi Arabia	Ras Tanura: C	1	130	O	Baldwin-Lima-Hamilton	1
Saudi Arabia	Ras Tanura: D	2	260	O	Baldwin-Lima-Hamilton	1
Saudi Arabia	Ras Tanura: E (Aramco)	5	250	O	Baldwin-Lima-Hamilton	1
US: Alabama	Mobile	2	230	O	Baldwin-Lima-Hamilton	1
Alaska	Fairbanks	1	100	O	Baldwin-Lima-Hamilton	1
California	Etiwanda	2	165	O	Baldwin-Lima-Hamilton	1
California	Pittsburg	2	180	O	Baldwin-Lima-Hamilton	1
California	Redondo	1	100	O	Baldwin-Lima-Hamilton	1
California	South Bay: C-(2 locations)	8	300	O	---	1
California	Vernon	1	100	O	Baldwin-Lima-Hamilton	1

Submerged Tube (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Colorado	Lacombe	1	140	O	Baldwin-Lima-Hamilton	1
Georgia	Georgia River	1	115	O	Baldwin-Lima-Hamilton	1
Georgia	Krannert	2	200	O	Baldwin-Lima-Hamilton	1
Georgia	Yates	1	115	O	Baldwin-Lima-Hamilton	1
Illinois	Chicago: A	2	200	O	Baldwin-Lima-Hamilton	1
Illinois	Chicago: B	2	145	O	Baldwin-Lima-Hamilton	1
Illinois	Chicago: C	2	144	O	Baldwin-Lima-Hamilton	1
Illinois	Chicago: D	2	145	O	Baldwin-Lima-Hamilton	1
Illinois	Stickney	2	120	O	Baldwin-Lima-Hamilton	1
Indiana	Fayette	2	100	O	Baldwin-Lima-Hamilton	1
Indiana	South Bend: A	1	150	O	Baldwin-Lima-Hamilton	1
Indiana	South Bend: B	2	150	O	Baldwin-Lima-Hamilton	1
Indiana	Tanners Creek	1	145	O	Baldwin-Lima-Hamilton	1
Louisiana	Kaiser Chem.	8	120	O	Baldwin-Lima-Hamilton	1
Louisiana	New Orleans: A	1	100	O	Baldwin-Lima-Hamilton	1
Michigan	Belle River	2	140	O	Baldwin-Lima-Hamilton	1
Michigan	Trenton	1	137	O	Baldwin-Lima-Hamilton	1
Minnesota	Cloquet	1	290	O	Baldwin-Lima-Hamilton	1

Submerged Tube (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Mississippi	Gulf Coast Sta	1	100	O	Baldwin-Lima-Hamilton	1
Missouri	Kansas City	1	115	O	Baldwin-Lima-Hamilton	1
Missouri	St. Louis	1	115	O	Baldwin-Lima-Hamilton	1
New Jersey	Camden	1	100	O	Baldwin-Lima-Hamilton	1
New Mexico	Albuquerque: C	3	150	O	Baldwin-Lima-Hamilton	1
New York	Astoria	2	440	O	Baldwin-Lima-Hamilton	1
New York	Barrett	1	115	O	Baldwin-Lima-Hamilton	1
New York	Hemstead-Oceanside Incinerator	4	450	O	A. M. F.	3
New York	Indian Point	2	500	O	Baldwin-Lima-Hamilton	1
New York	Niagra Falls	3	500	O	Baldwin-Lima-Hamilton	1
New York	Port Jefferson: A	1	115	O	Baldwin-Lima-Hamilton	1
New York	Port Jefferson: C	1	115	O	Baldwin-Lima-Hamilton	1
New York	Staten Is.	1	220	O	Baldwin-Lima-Hamilton	1
N. Dakota	Grafton	1	100	O	Baldwin-Lima-Hamilton	1
Ohio	A. E. P.	1	135	O	Baldwin-Lima-Hamilton	1
Ohio	Dayton: C	1	115	O	Baldwin-Lima-Hamilton	1
Ohio	Kammer: A	2	270	O	Baldwin-Lima-Hamilton	1
Ohio	Kammer: B	1	140	O	Baldwin-Lima-Hamilton	1

Submerged Tube (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Ohio	Muskingum (Ohio Pwr)	1	140	O	Baldwin-Lima-Hamilton	1
Ohio	Relief	2	166	O	Baldwin-Lima-Hamilton	1
Pennsyl-vania	Hershey	1	100	O	Baldwin-Lima-Hamilton	1
Pennsyl-vania	Marcus Hook	1	300	O	Westinghouse	1
Pennsyl-vania	Pittsbrugh (Alcoa)	1	122	O	Baldwin-Lima-Hamilton	1
Tennessee	Blair: B	2	145	O	Baldwin-Lima-Hamilton	1
Tennessee	Gallatin	2	300	O	Baldwin-Lima-Hamilton	1
Tennessee	Gallatin Sta	2	190	O	Baldwin-Lima-Hamilton	1
Tennessee	Kingston	4	300	O	Baldwin-Lima-Hamilton	1
Tennessee	Widows Creek	1	210	O	Baldwin-Lima-Hamilton	1
Texas	Grand Prairie	1	160	O	Baldwin-Lima-Hamilton	1
Texas	Sandou	3	216	O	Baldwin-Lima-Hamilton	1
Texas	Texas City	1	140	O	Baldwin-Lima-Hamilton	1
Virginia	Portsmouth	1	100	O	Baldwin-Lima-Hamilton	1
Virginia	Possum Pt: A	1	100	O	Baldwin-Lima-Hamilton	1
Virginia	Wheelwright	2	130	O	Baldwin-Lima-Hamilton	1
W. Virginia	A. E. P.: A	1	140	O	Baldwin-Lima-Hamilton	1
W. Virginia	A. E. P.: B	3	720	O	Baldwin-Lima-Hamilton	1
W. Virginia	A. E. P.: C	6	470	O	Baldwin-Lima-Hamilton	1
W. Virginia	Glasgow	1	100	O	Baldwin-Lima-Hamilton	1

Submerged Tube (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
USSR	Location Unknown	3	233	O	Baldwin-Lima-Hamilton	1
USSR	Location Unknown	8	290	O	Baldwin-Lima-Hamilton	1
Venezuela	Las Piedras	1	450	-	Baldwin-Lima-Hamilton	8

Distillation*

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Australia	Morwell	4	230.4	O	Aiton & Co (England)	1, 2
Australia	Osborne: B	1	115.2	O	Aiton & Co	1, 2
Australia	Tallawarra	2	144	O	Aiton & Co	1, 2
Canada	Saskatchewan: A	1	100.8	-	Aiton & Co	1, 2
England	Bold, St. Helens	3	172.8	O	Aiton & Co	1, 2
England	Brighton	4	138.2	O	Aiton & Co	1, 2
England	Brimsdown	3	144	O	Aiton & Co	1, 2
England	Carmarthen Bay, Burry Port	3	172.8	O	Aiton & Co	1, 2
England	Carrington, Manchester	2	144	O	Aiton & Co	1, 2
England	Chester	2	172.8	O	Aiton & Co	1, 2
England	Dagenham	5	384	O	Aiton & Co	1, 2
England	Darwen, Lancashire	2	172.8	O	Aiton & Co	1, 2
England	Derby	5	111.1	O	Aiton & Co	1, 2
England	Drakelow: A, Burton-upon-Trent	3	216	O	Aiton & Co	1, 2
England	Drakelow: B, Burton-upon-Trent	8	460.8	O	Aiton & Co	1, 2
England	Drakelow: C, Burton-upon-Trent	4	295.2	O	Aiton & Co	1, 2

* Aiton plants include vertical straight-tube directly heated type, vertical straight-tube thermo-compression type, vertical straight-tube high-efficienty bleed steam type, F. T. horizontal removable-tube-bundle type, MSF type and submerged tube type. Reference 1, 2 contain no differentiation as to the type of distillation plant.

Distillation (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
England	E. Yelland, Barnstaple	3	216	O	Aiton & Co (England)	1, 2
England	Eggborough, Yorks	4	403.2	O	Aiton & Co	1, 2
England	Ferrybridge: C	1	748.8	O	Aiton & Co	1, 2
England	Fleetwood	2	144	O	Aiton & Co	1, 2
England	Fulham, London	2	144	O	Aiton & Co	1, 2
England	Grimethorpe, Barnsley	3	216	O	Aiton & Co	1, 2
England	Hams Hall: B, Birmingham	2	129.6	O	Aiton & Co	1, 2
England	Hams Hall: C, Birmingham	6	432	O	Aiton & Co	1, 2
England	Hayes, London	2	121.2	O	Aiton & Co	1, 2
England	High Marnham	5	432	O	Aiton & Co	1, 2
England	High Marnham, Newark-upon-Trent	5	432	O	Aiton & Co	1, 2
England	Huddersfield	2	115.2	O	Aiton & Co	1, 2
England	Ilkeston, Derby	4	230.4	O	Aiton & Co	1, 2
England	Ince, Ellesmere Port	3	259.2	O	Aiton & Co	1, 2
England	Ironbridge "B"	2	200	O	Aiton & Co	1, 2
England	Keadby, Scunthorpe	3	259.2	O	Aiton & Co	1, 2
England	Kearsley, Leeds	4	259.2	O	Aiton & Co	1, 2
England	Littlebrook, Dartford	4	345.6	O	Aiton & Co	1, 2
England	Liverpool	2	144	O	Aiton & Co	1, 2

Distillation (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
England	Manvers Main, Mexborough	5	385.2	O	Aiton & Co (England)	1,2
England	Marchwood	2	172.8	O	Aiton & Co	1,2
England	Murton, Durham	2	144	O	Aiton & Co	1,2
England	Neepsend, Sheffield	2	115.2	O	Aiton & Co	1,2
England	Norwich	3	103.1	O	Aiton & Co	1,2
England	Ocker Hill, Wolverhampton	3	129.6	O	Aiton & Co	1,2
England	Poplar, London	4	230.4	O	Aiton & Co	1,2
England	Portishead "B", Bristol	5	360	O	Aiton & Co	1,2
England	Ratcliffe-on-Soar	1	748.8	O	Aiton & Co	1,2
England	Roosecote, Barrow-in-Furness	3	172.8	O	Aiton & Co	1,2
England	Rotherham	2	144	O	Aiton & Co	1,2
England	Ryehouse, London	5	158.4	O	Aiton & Co	1,2
England	Scunthorpe	3	201.6	O	Aiton & Co	1,2
England	Skelton Grange Leeds	2	172.8	O	Aiton & Co	1.2
England	South Denes	4	200	O	Aiton & Co	1,2
England	Staythorpe: A, Newark-upon-Trent	6	432	O	Aiton & Co	1,2
England	Sunderland	3	106.6	O	Aiton & Co	1,2
England	Thornhill, Dewsbury	2	115.2	O	Aiton & Co	1,2
England	Tilbury: A	6	240	O	Aiton & Co	1,2

Distillation (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
England	Tilbury: B	4	635	O	Aiton & Co (England)	1, 2
England	Wakefield	2	172.8	O	Aiton & Co	1, 2
England	Walsall	4	172.8	O	Aiton & Co	1, 2
England	Warrington	3	172.8	O	Aiton & Co	1, 2
England	W. Thurrock	5	560	O	Aiton & Co	1, 2
England	Willesden: Taylors Lane, London	3	100.8	O	Aiton & Co	1, 2
England	Woolwich	4	253.4	O	Aiton & Co	1, 2
Hong Kong (British)	North Point: B	3	186.6	O	Aiton & Co	1, 2
Ireland (N)	Carrickfergus	2	144	O	Aiton & Co	1, 2
Scotland	Edinburg	4	273.6	O	Aiton & Co	1, 2
So. Africa	Umgeni	3	216	O	Aiton & Co	1, 2
UAR (Egypt)	Cairo South	2	201.6	O	Aiton & Co	1, 2

Vapor Compression

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Bermuda (British) W. Indies	Kindley AFB: B	4	200	O	Aqua-Chem, Inc	1
Ecuador	Salinas: A	2	100	O	Aqua-Chem, Inc	1
Saudi Arabia	Dhahran: B	4	200	O	Aqua-Chem, Inc	1
California	Los Angeles (Arrowhead)	2	100	O	Aqua-Chem, Inc	1
New Mexico	Roswell	1	1,000	O	Chicago Bridge & Iron Co	1
Marshall Is.	---	1	692	O	Aqua-Chem Inc	10

Multieffect Multistage Flash

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
United States						
California	San Diego	1	1,000	C	Aqua-Chem, Inc	1
New York	Riverhead, Long Is.	1	1,000	C	AMF	5

Vacuum Freezing - Vapor Compression

Country	Location	No. of Unit	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Israel	Eilat: B	4	250	O	Colt Industries & Desalination Engineering (Israel)	1
United States No. Carolina	Wrightsville Beach: C	1	125*	O	Colt Industries	1

* following modifications

Direct Freezing - Secondary Refrigerant

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Unites States						
No. Carolina	Wrightsville Beach: A	1	200	X	Struthers Scientific	1
No. Carolina	Wrightsville Beach	1	15	O	Struthers Scientific	1

Hydrate Crystallization

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
United States						
No. Carolina	Wrightsville Beach	1	20	O	Sweet Water Development Co	1
No. Carolina	Wrightsville Beach	1	10	C	Koppers Co	6

Electrodialysis Process

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Australia	Exmouth Gulf	1	60	C	Ionics, Inc	1
Bahrain	Awali (Manama)	2	100	O	Ionics, Inc	1,4
Bermuda (British) W. Indies	Bermudiana Hotel: C	1	48	C	Ionics, Inc	1
Israel	T'Zeelim	-	132	C	--	1
Kuwait	Shuwaika (Kuwait Oil Co.): C	1	240	O	Ionics, Inc	1,4
Kuwait	Wafra (Neutral zone)	1	48	O	Ionics, Inc	1,4
Libya	Al-Adem	2	86	O	Ionics, Inc	1
Liechten-stein	Zilton	-	115	O	William Body & Co.(England)	1
Saudi Arabia	Dhahran: A	2	115.2	O	Ionics, Inc	1,4
S. Africa	Welkom	4	2,900	X	--	1
Spanish Sahara	Bucrea	1	26	C	Ionics, Inc	1,4
Tunisia	Djerba Island	-	26.5	O	Ionics, Inc	1,4
Tunisia	Houmt Souk	-	40	O	--	1
Tunisia	El Bourma	-	28.8	O	Ionics, Inc	1,4
Arizona	Buckeye	1	650	O	Ionics, Inc	1,4
Arizona	Winslow	1	35	O	Ionics, Inc	1
California	Coalinga	1	28	O	Ionics, Inc	1,4
Illinois	Hanna City (AF)	1	70	O	Ionics, Inc	1,4
Montana	Havre (AF)		56	O	Ionics, Inc	1
N. Dakota	Fortuna (AF)	-	44.5	O	Ionics, Inc	1
S. Dakota	Gettysburg (AF)	1	40	O	Ionics, Inc	1
S. Dakota	Webster	1	250	O	Asahi Chemical Co (Japan)	1
Texas	Port Mans-field	-	250	O	Ionics, Inc	1,4
Holland	--	-	150	O	Boby-Bronswerk	-
Tunisia	Zarzis	-	6.6	O	Ionics, Inc	4

Electrodialysis Process (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
Libya	AGIP Mineraria	-	10	O	Ionics, Inc	4
Libya	Santa Fe Drilling Co	-	6	O	Ionics, Inc	4
Libya	Esso Libya	-	4	O	Ionics, Inc	4
Libya	Mobil Oil	-	8	O	Ionics, Inc	4
Libya	--	-	100	O	Boby-Bronswerk	14
Iran	National Iranian Oil Co.	-	12	O	Ionics, Inc	4
Algeria	Sinclair Mediterranean Petroleum	-	7.2	O	Ionics, Inc	4
Tunisia	TRAPSA, French Pipeline Co.	-	20	O	Ionics, Inc	4
N. Africa	French Army	-	15	O	Ionics, Inc	4
Libya	Royal Air Force - El Adem		10	O	Ionics, Inc	4
Montana	U.S. Air Force, Havre	-	14	O	Ionics, Inc	4
Philippines	Subic Bay	-	6	O	Ionics, Inc	4
Bahrain	A. Algosaibi Brothers	-	4.8	O	Ionics, Inc	4
Italy	Palermo, Sicily	-	6	O	Ionics, Inc	4
Spanish Sahara	Edasa	-	6	O	Ionics, Inc	4
Bahrain	Mission of California	-	3	O	Ionics, Inc	4
Bahrain	Stimlo Beverage Co	-	6	O	Ionics, Inc	4
Bermuda	Elbow Beach Surf Club	-	13	O	Ionics, Inc	4
New York	Junius Ponds	-	12	O	Ionics, Inc	4

Electrodialysis Process (Cont'd)

Country	Location	No. of Units	Total Capacity (1000 gpd)	Status	Manufacturer	Ref
British West Indies	Antigua - Private Estate	-	1.4	O	Ionics, Inc	4
Bahrain	Government Hospital	-	18	O	Ionics, Inc	4
Virgin Islands	St. Croix	-	20	O	Ionics, Inc	4
Utah	Saltair	-	12	O	Ionics, Inc	4
Utah	Hanksville	-	6	O	Ionics, Inc	4
Texas	Laredo	-	1.2	O	Ionics, Inc	4
Bahrain	Water Bottlers	-	4.8	O	Ionics, Inc	4

Reverse Osmosis

Country	Location	No. of Units	Total* Capacity (1000 gpd)	Status	Manufacturer	Ref
California	Coalinga	1	7	O	University of Calif	11
California	Mobile**	4	8	O	Aerojet-General Corp	12
California	--	1	10	O	Aerojet-General Corp	12
California	--	1	40	O	Aerojet-General Corp	12
California	--	1	50	C	Aerojet-General Corp	12
California	Trans-portable***	1	1.4	O	General Dynamics	13
Italy	--	1	10	O	General Dynamics	13

* Capacity on brackish water

** Four mobile units, each with a nominal capacity of 1,000 gpd processing seawater, or 2,000 gpd on brackish water

*** This unit was exhibited at the First International Symposium on Water Desalination in Washington, D. C., Oct 1965.

References

1. 1965 Saline Water Conversion Report, U.S. Department of the Interior, Office of Saline Water

2. List of Land-Based Water Distillation Plants, Aiton & Co. Ltd., Derby, England

3. "Refuse Furnace to Desalt Water," Engineering News-Record, August 19, 1965

4. Typical Ionics Installations, Ionics, Inc

5. "AMF to Develop, Design Nation's First Nuclear-Powered Water Desalting Plant for New York State at Riverhead, Long Island." Press Release July 19, 1965

6. 1964 Saline Water Conversion Report, U.S. Department of the Interior, Office of Saline Water

7. Gaunt, R. E., "Experience in Multistage Flash Process," Paper SWD/101, presented at 1965 First International Symposium on Water Desalination Table I, "Westinghouse Flash-type Evaporators Installed or On Order as of August 1, 1965"

8. "Water Production Evaporators, Worldwide Installation List," Westinghouse Proposal Descriptive Leaflet 1360-6, September 1965

9. "Westinghouse Flash-Type Evpaorators," Westinghouse, Proposal Leaflet 1360 1, September 1965

10. "Aqua-Chem's Stationary Seawater Distilling Plants," Aqua-Chem, Inc, Leaflet C19-4255. August 1965

11. "Reverse Osmosis Unit Desalts Water for City Mains," Chemical Engineering, August 2, 1965

12. Letter from Mr. M.A. Jarvis, Aerojet-General Corporation, to Mr. J.R. Wilson Kaiser Engineers, November 15, 1966

13. Letter from Mr. D.M. Fouquet, General Atomic Div, General Dynamics Corporation, to Mr. J.R. Wilson, December 28, 1966

14. Burley, M.J., and Mower, P.A., "Desalination as a Supplement to Conventional Water Supply - 1," Technical Paper TP. 50 The Water Research Association

APPENDIX B

TECHNICAL DATA

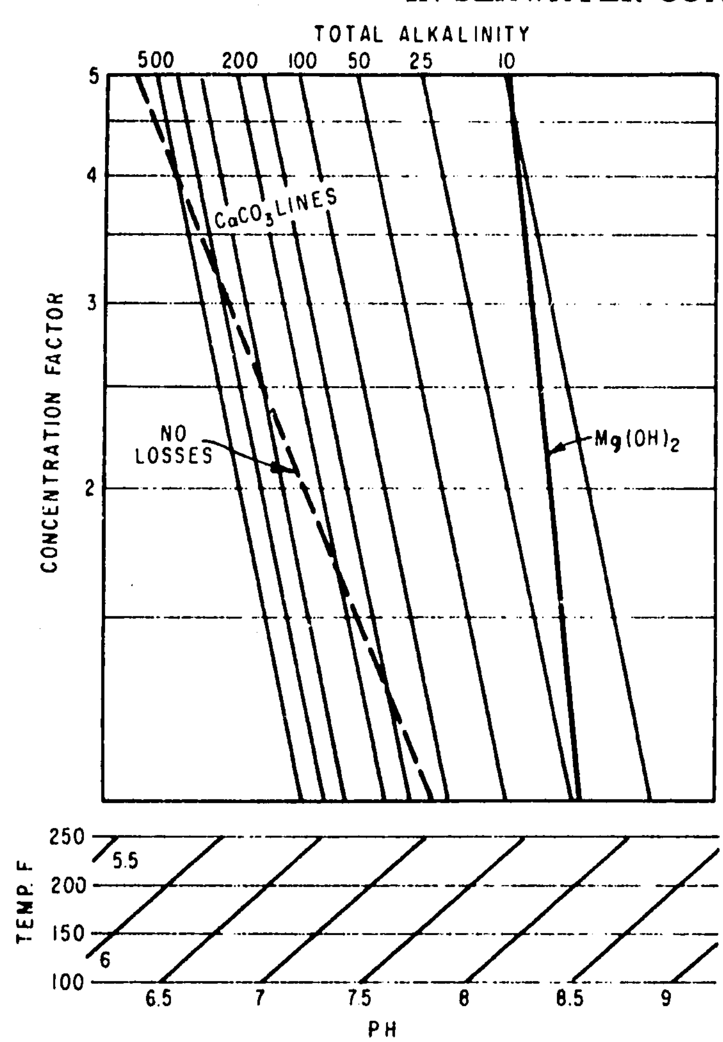
TABLE OF CONTENTS

Handy Water Equivalents

1 million gallon = 3.07 acre feet = 264,120 meter^3

¢/1,000 gal.	¢/meter^3	$/acre ft	¢/1,000 gal.	¢/meter^3	$/acre ft
5	1.3	16.30	55	14.5	179.25
10	2.6	32.59	60	15.8	195.54
15	4.0	48.89	65	17.2	211.84
20	5.3	65.18	70	18.5	228.13
25	6.6	81.48	75	19.8	244.43
30	7.9	97.77	80	21.1	260.72
35	9.2	114.07	85	22.5	277.02
40	10.6	130.36	90	23.8	293.31
45	11.9	146.66	95	25.1	309.61
50	13.2	162.95	100	26.4	325.90

SOLUBILITY OF $CaCO_3$ AND $Mg(OH)_2$
IN SEAWATER CONCENTRATES



Source:

Standiford, F. C. and Sinek, J. R., "Stop Scale in Seawater Evaporators," Chemical Engineering Progress, pp 58 to 63, Jan 1961

DISCUSSION ON THE USE OF STABILITY DIAGRAMS

Stability diagrams are used to solve problems involving the scale-forming properties of water. Actually, stability diagrams are solubility charts for the scale-forming compounds. The word "stability" has been used because these diagrams are intended to indicate the extent of departure from equilibrium conditions of saturation.

In order to estimate whether a sample of water is saturated with respect to a particular scale-forming constituent, the saturation pH (designated pH_s) as read from the appropriate diagram* is compared to the actual pH of the sample. If the difference ($pH-pH_s$), designated the "saturation index", is positive the sample is supersaturated with respect to the particular constituent and scale-forming tendencies are indicated; if negative, it is undersaturated and corrosive tendencies are indicated. It is to be emphasized that the calculated indices are a measure of the departure from equilibrium, and as such do not predict the time required to reach equilibrium. Hence, some judgement must be exercised in the interpretation of the index. The substance(s) which will actually precipitate from a supersaturated solution under given conditions is dependent on a time factor.

The scale-forming constituents in natural water for which charts are provided are calcium carbonate (OSW 10.151) and magnesium hydroxide (OSW 10.152). For concentrated sea water, charts are included for calcium carbonate (OSW 11.151), magnesium hydroxide (OSW 11.152), and calcium sulfate (OSW 11.153). In the case of natural waters, charts are also included to estimate the free carbon dioxide concentration (OSW 10.153) and the carbonate and hydroxide concentrations (OSW 10.154). A sample calculation is provided on each chart; additional calculations involving these diagrams are discussed in detail by Langelier[1].

The diagrams pertaining to concentrated sea water may also be used for similar saline waters (harbor waters, etc.) provided the total alkalinity is due only to bicarbonate. These diagrams were designed for waters having a total mineral content between 25,000 and 100,000 mg. per liter. The diagrams pertaining to natural waters are recommended for waters, containing 200 to 1000 mg. per liter total solids.

In the use of these charts the total alkalinity is taken as the sum of the carbonate, bicarbonate, and hydroxide concentrations, all expressed in ppm as equivalent calcium carbonate ($CaCO_3$).

It is to be noted that the 167°F charts for natural waters require the pH of the water at 167°F. The analytical pH values measured at 77°F may be converted to their values at 167°F by using the chart[1] on page 2 of this discussion.

REFERENCES FOR THIS DISCUSSION

1. Langelier, W. F., "Chemical Equilibria in Water Treatment", Journal, American Water Works Association, 38, 169 (1946).

2. Langelier, W. F., Caldwell, D. H., and Lawrence, W. B., "Causes and Preventives of Scale and Corrosion in Thermocompression Equipment when Employed for the Distillation of Sea Water", Institute of Engineering Research Report (August 15, 1950), University of California, Berkeley, California.

3. Langelier, W. F., Caldwell, D. H., and Lawrence, W. B., "Scale Control in Sea Water Distillation Equipment", Ind. Eng. Chem., 42, 126 (1950).

4. "Water Quality and Treatment", Second Edition, American Water Works Association, Inc., New York, pp. 291-298 (1950).

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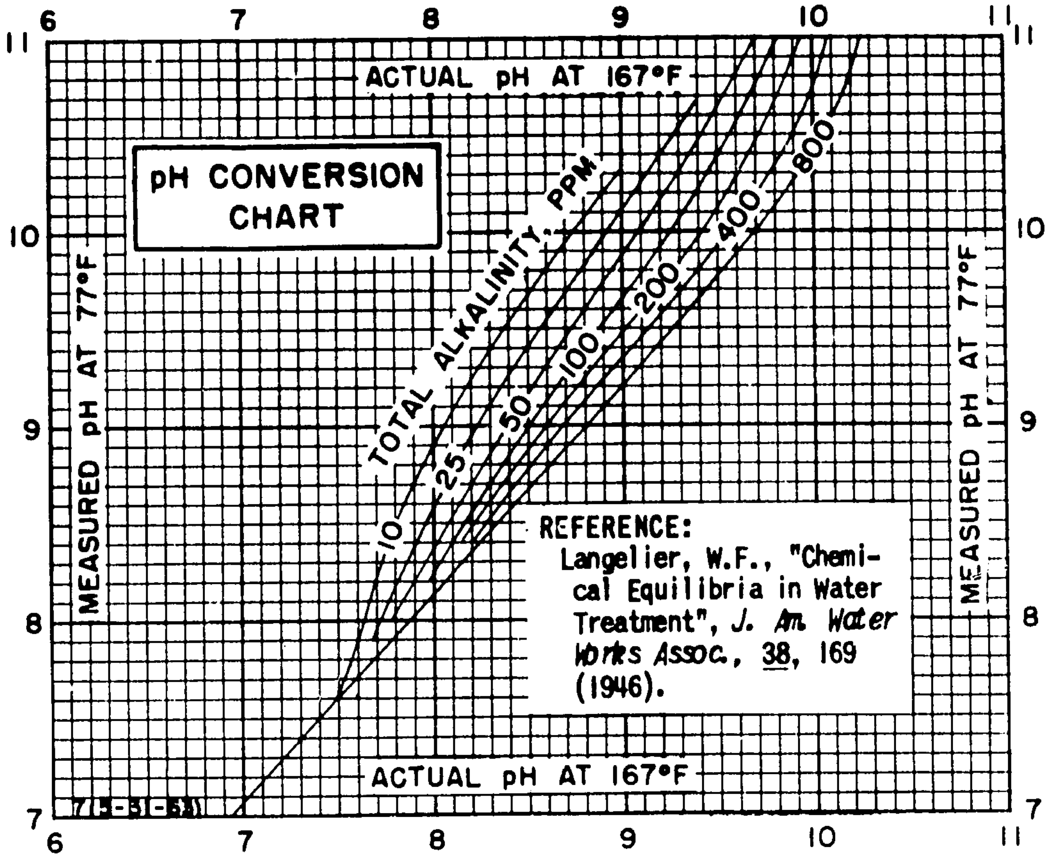
* An exception exists in the case of calcium sulfate in concentrated sea water (OSW 11.153). Here, a saturation index, as defined above, is not calculated; however, the use of the diagram is clear from the numerical example appearing on OSW 11.153.



CONVERSION FACTORS TO CONVERT PPM TO PPM AS EQUIVALENT $CaCO_3$

COMPOUND OR ION	TO CONVERT FROM PPM TO PPM AS EQUIVALENT $CaCO_3$, MULTIPLY BY:
CALCIUM, Ca	2.50
MAGNESIUM, Mg	4.12
CARBONIC ACID, H_2CO_3	1.61
MAGNESIUM HYDROXIDE, $Mg(OH)_2$	1.72
CARBON DIOXIDE, CO_2	2.27
HYDROXIDE ION, OH^-	5.88
BICARBONATE ION, HCO_3^-	1.64
CARBONATE ION, CO_3^{--}	1.67

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TECHNICAL DATA BOOK
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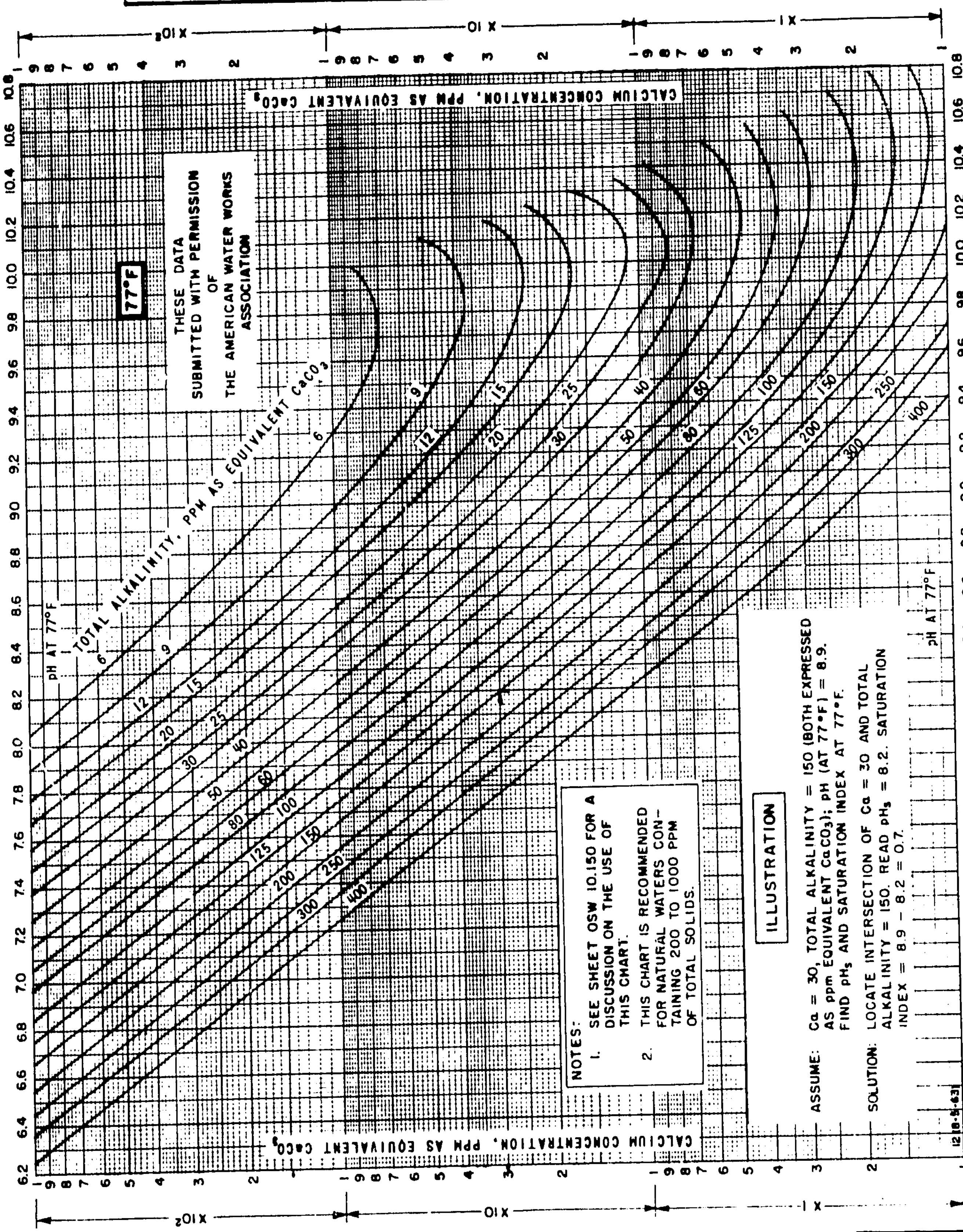
SHEET OSW 10.150
ED W.C.S. DATE 5-63

CALCIUM CARBONATE IN NATURAL WATERS

STABILITY DIAGRAM



REFERENCE:

Langelier, W.F., "Chemical Equilibria in Water Treatment", *J. Am. Water Works Assoc.*, 38, No. 2, 169 (February 1946).

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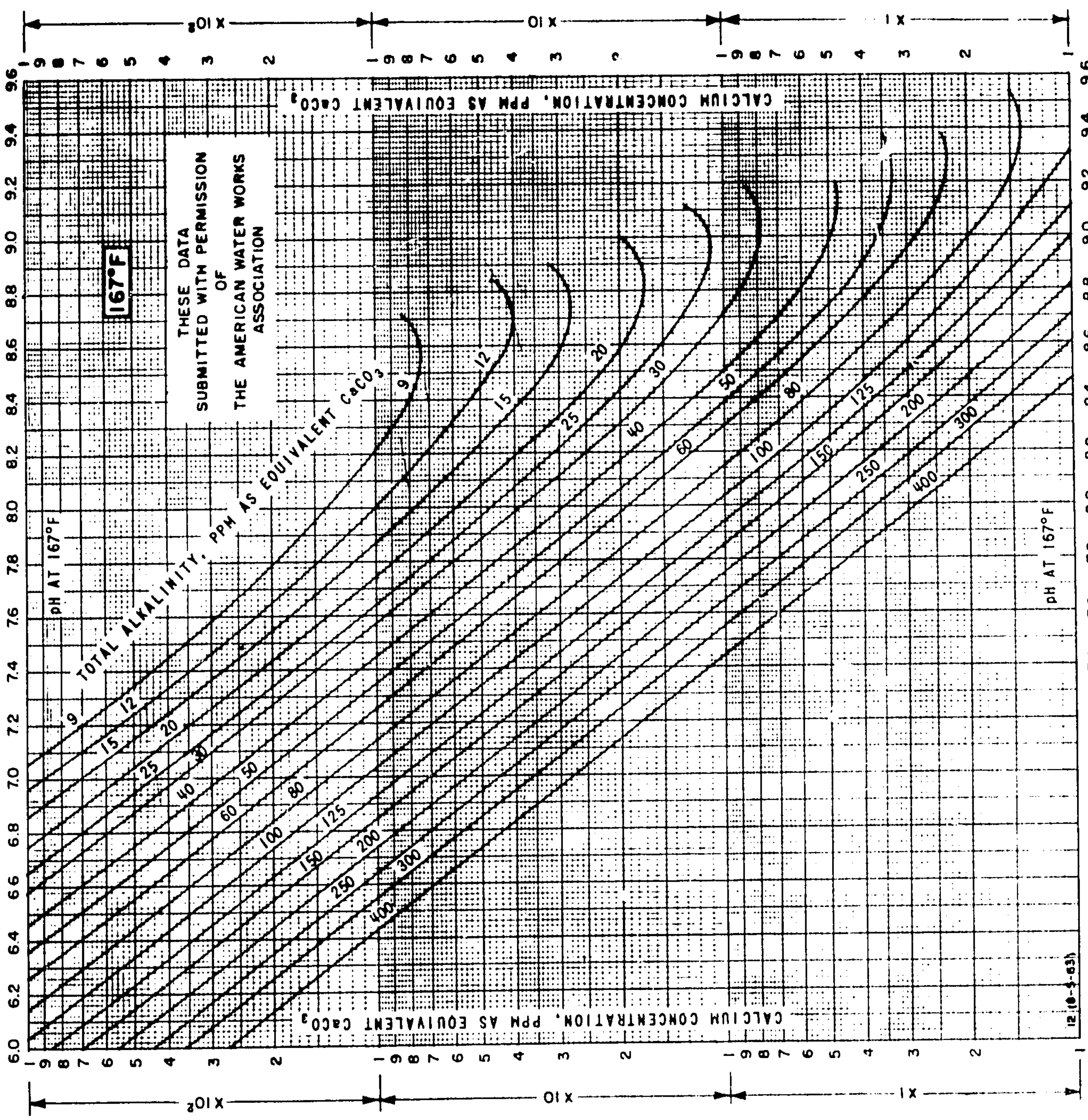
TECHNICAL DATA BOOK
OFFICE OF SALINE WATER
OSW 10.151
DATE 12-63

CALCIUM CARBONATE IN NATURAL WATERS

STABILITY DIAGRAM



NOTES:

1. SEE SHEET OSW 10.150 FOR pH CONVERSION CHART AND FOR A DISCUSSION ON THE USE OF THIS CHART.
2. THIS CHART IS RECOMMENDED FOR NATURAL WATERS CONTAINING 200 TO 1000 PPM OF TOTAL SOLIDS.

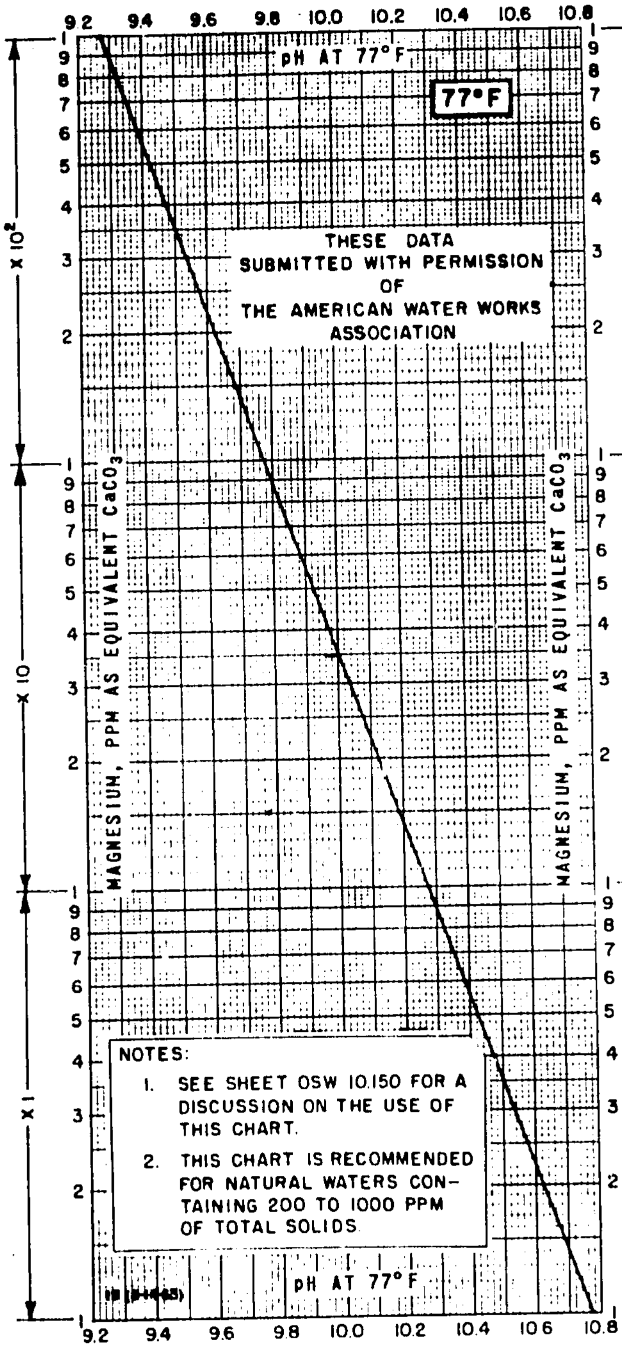
FOR REFERENCE SEE PAGE ONE.

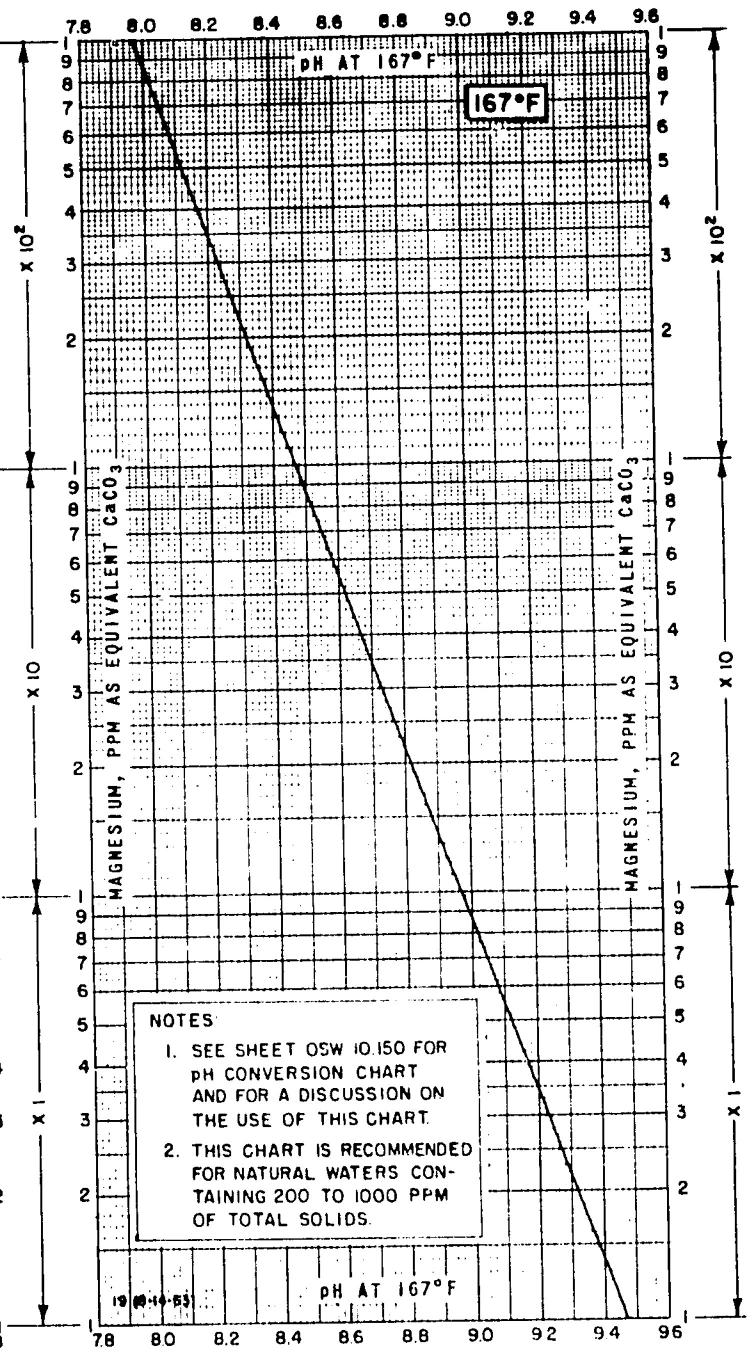
THIS CHART PREPARED BY THE M.W. KELLOGG CO. FOR THE OFFICE OF SALINE WATER U.S. DEPT. OF THE INTERIOR UNDER CONTRACT NO. 14-01-0001-357

TECHNICAL DATA BOOK
OFFICE OF SALINE WATER
OSW 10.151
DATE 12-63

MAGNESIUM HYDROXIDE IN NATURAL WATERS

STABILITY DIAGRAM





ILLUSTRATION

ASSUME: Mg = 35 PPM AS EQUIVALENT $CaCO_3$, AND pH (AT 77°F) = 9.0. FIND THE SATURATION pH AND SATURATION INDEX WITH RESPECT TO MAGNESIUM HYDROXIDE AT 77°F.

SOLUTION: LOCATE INTERSECTION OF Mg = 35 AND 77°F CURVE. READ pH_s = 10.0 SATURATION INDEX = 9.0 − 10.0 = −1.0.

REFERENCE:

Langelier, W.F., "Chemical Equilibria in Water Treatment", *J. Am. Water Works Assoc.*, 38, No. 2, 169 (February 1946).

THIS CHART PREPARED BY THE M.W. KELLOGG CO. FOR THE OFFICE OF SALINE WATER U.S. DEPT. OF THE INTERIOR UNDER CONTRACT NO. 14-01-0001-357

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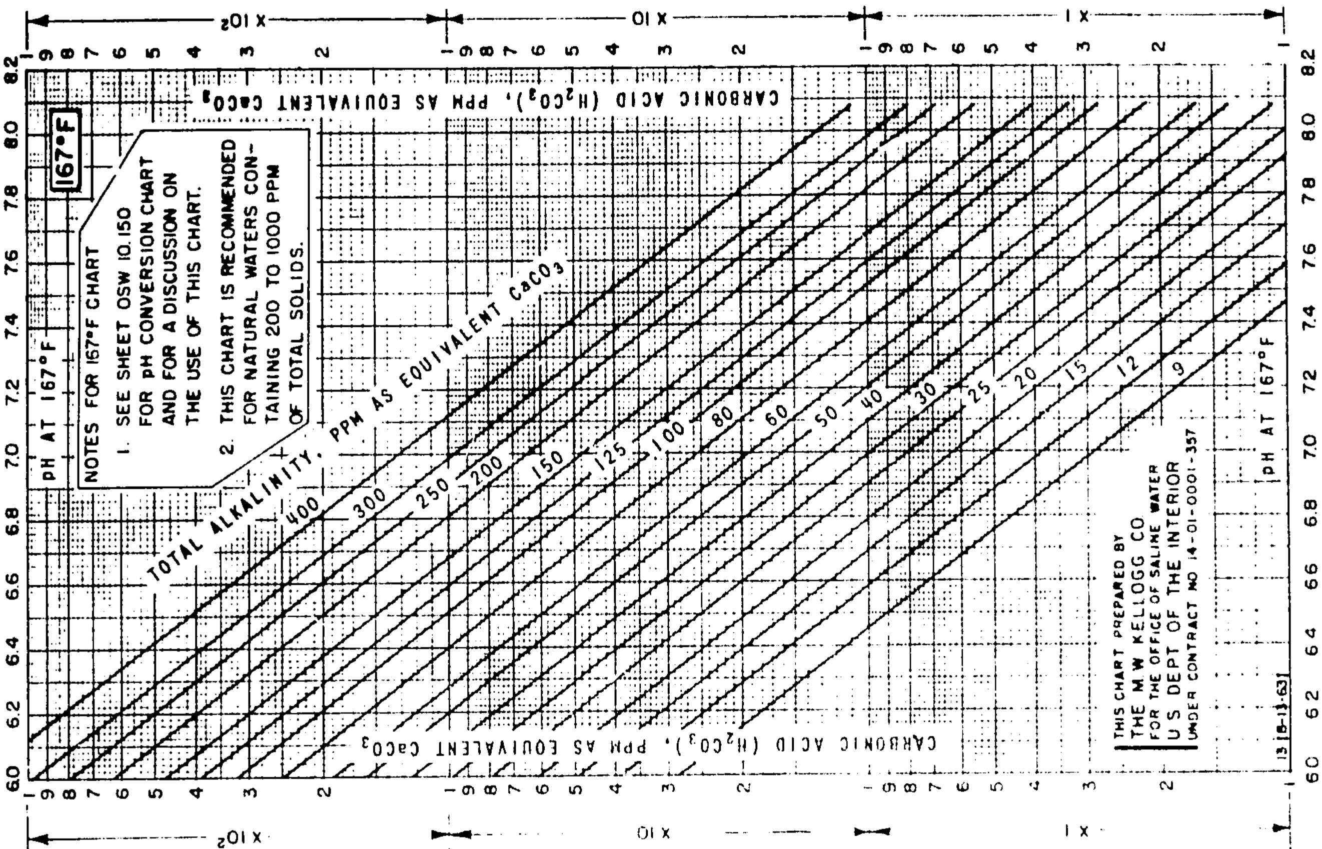
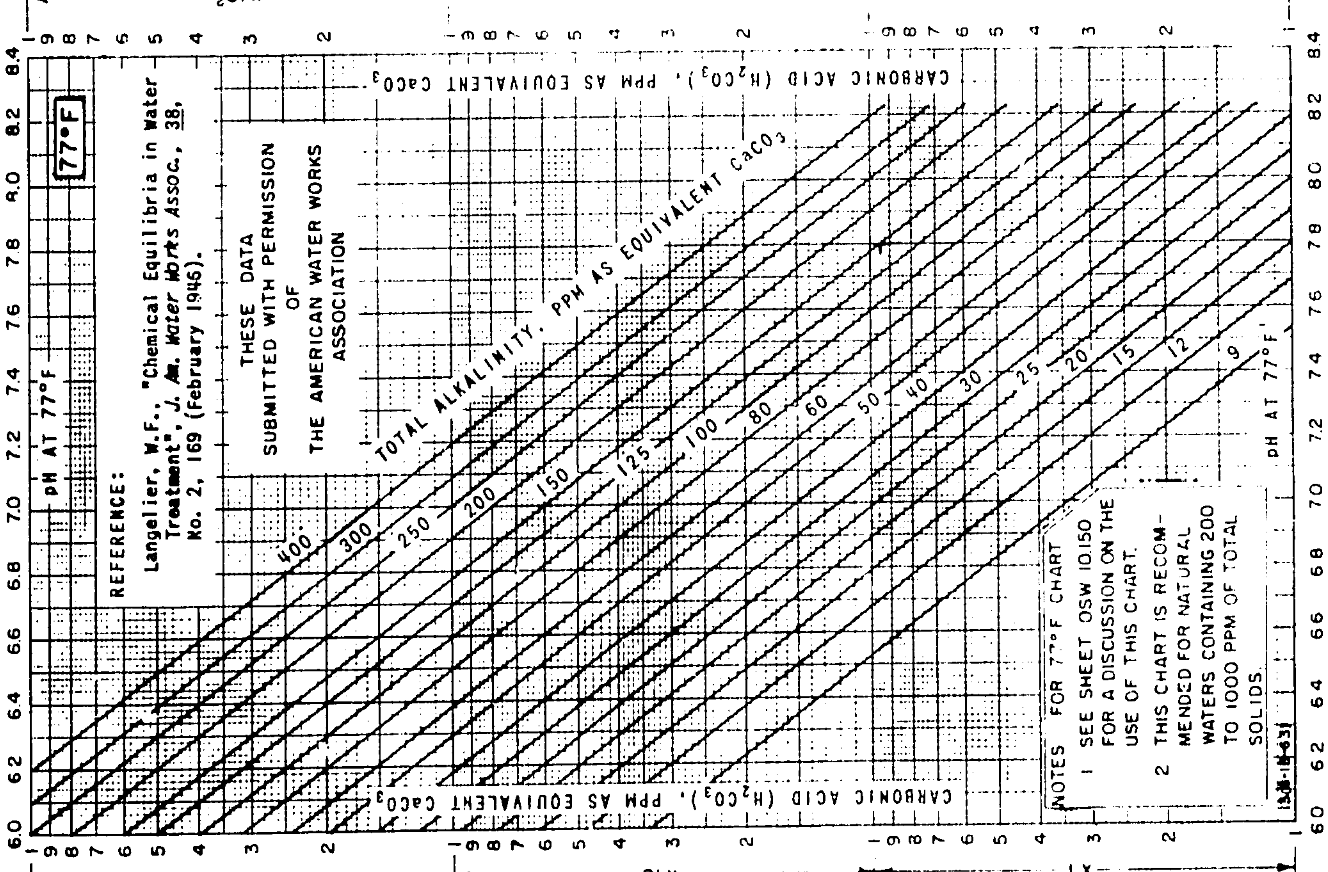
OSW 10.152
DATE 12-63

CARBONIC ACID IN NATURAL WATERS

EQUILIBRIUM CONCENTRATIONS





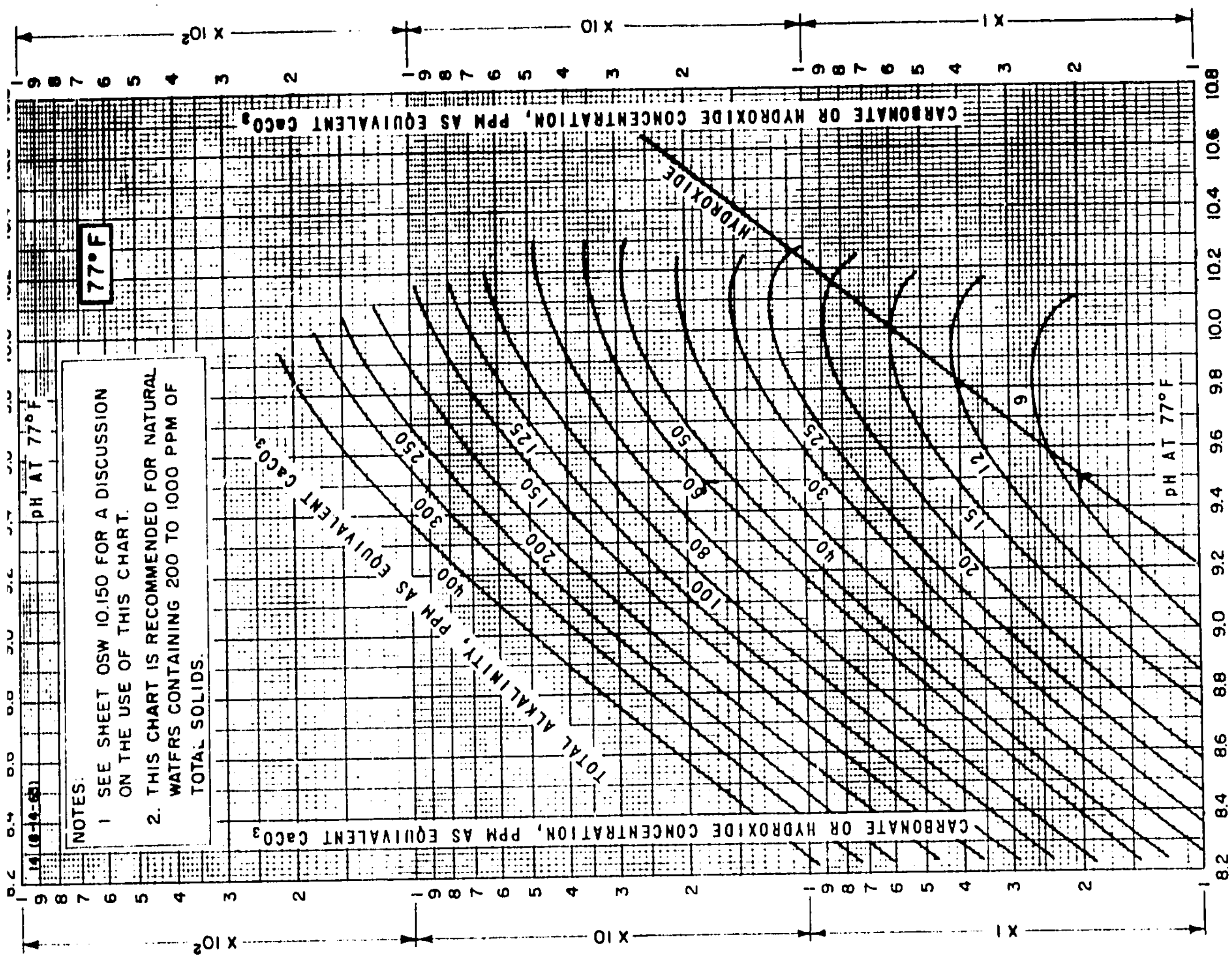
ILLUSTRATION

ASSUME TOTAL ALKALINITY = 150 PPM AS EQUIVALENT $CaCO_3$ pH (AT 77°F) = 7.8.
FIND EQUILIBRIUM CONCENTRATION OF H_2CO_3 AT 77°F.

SOLUTION: LOCATE INTERSECTION OF pH (AT 77°F) = 7.8 AND TOTAL ALKALINITY = 150. READ 9.5 PPM AS EQUIVALENT $CaCO_3$

CARBONATE AND HYDROXIDE IONS IN NATURAL WATERS

EQUILIBRIUM CONCENTRATIONS



ILLUSTRATION

ASSUME: TOTAL ALKALINITY = 60 PPM EQUIVALENT $CaCO_3$, pH (AT 77°F) = 9.5. FIND CONCENTRATIONS OF CO_3^{--}, OH^-, AND HCO_3^- AT 77°F.

SOLUTION:

CARBONATE: LOCATE INTERSECTION OF pH (AT 77°F) = 9.5 AND TOTAL ALKALINITY = 60. READ 18 PPM AS EQUIVALENT $CaCO_3$.

HYDROXIDE: LOCATE INTERSECTION OF HYDROXIDE LINE WITH pH (AT 77°F) = 9.5. READ 2 PPM EQUIVALENT $CaCO_3$.

BICARBONATE: SUBTRACT CARBONATE PLUS HYDROXIDE FROM TOTAL ALKALINITY. THUS, 60-(18+2) = 40 PPM AS EQUIVALENT $CaCO_3$.

THESE DATA SUBMITTED WITH PERMISSION OF THE AMERICAN WATER WORKS ASSOCIATION

REFERENCE:

Langelier, W.F., "Chemical Equilibria in Water Treatment", *J. Am. Water Works Assoc.*, 38, No. 2, 169 (February 1946).

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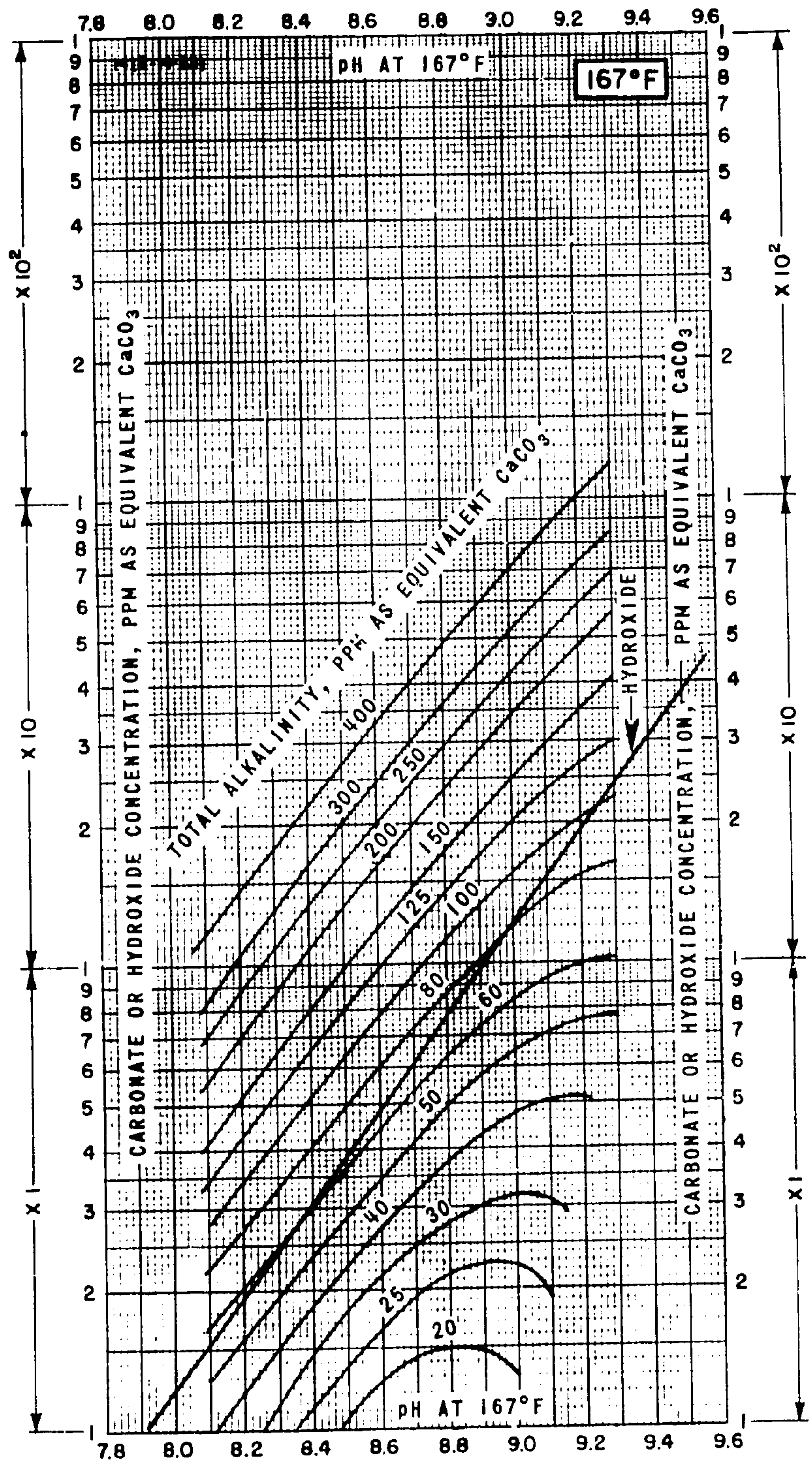
CARBONATE AND HYDROXIDE IONS IN NATURAL WATERS

EQUILIBRIUM CONCENTRATIONS



NOTES:

1. SEE SHEET OSW 10.150 FOR pH CONVERSION CHART AND FOR A DISCUSSION ON THE USE OF THIS CHART.
2. THIS CHART IS RECOMMENDED FOR NATURAL WATERS CONTAINING 200 TO 1000 PPM OF TOTAL SOLIDS.

THESE DATA SUBMITTED WITH PERMISSION OF THE AMERICAN WATER WORKS ASSOCIATION

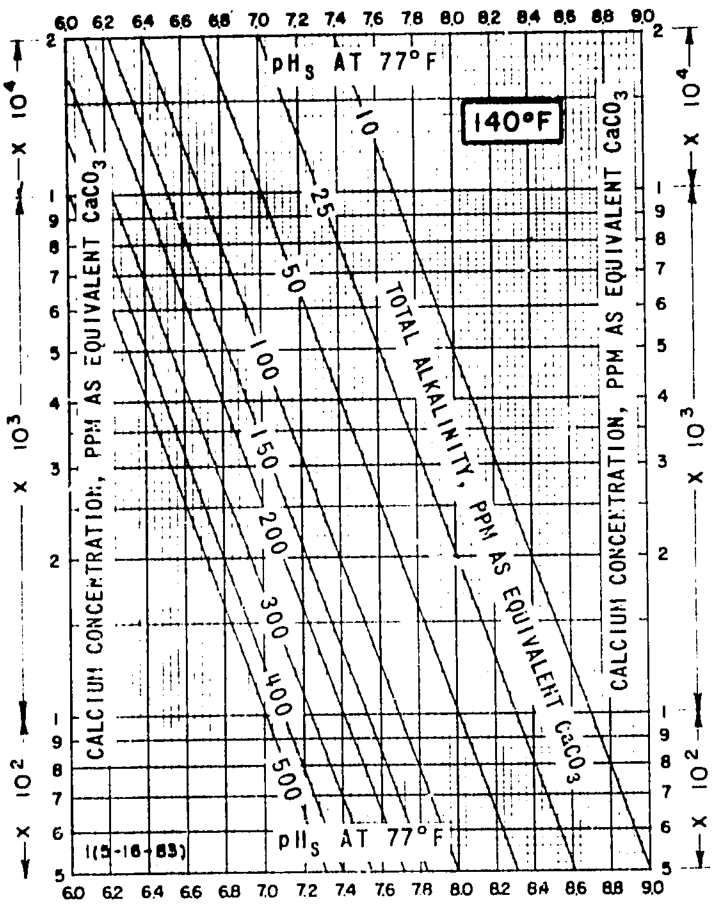
FOR REFERENCE SEE PAGE ONE.

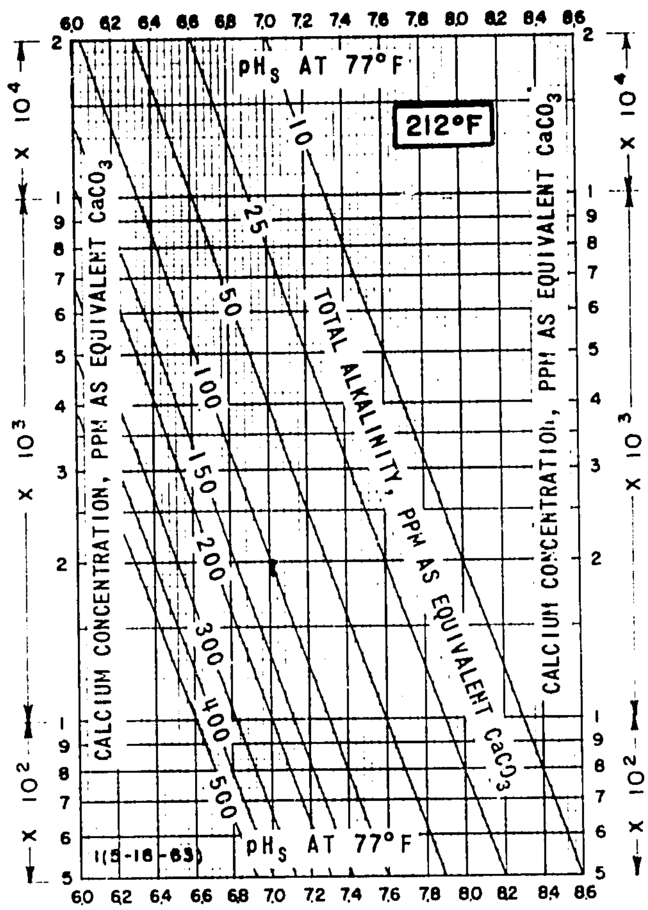
THIS CHART PREPARED BY
THE M.W. KELLOGG CO.
FOR THE OFFICE OF SALINE WATER
U.S. DEPT. OF THE INTERIOR
UNDER CONTRACT NO. 14-01-0001-357

TECHNICAL DATA BOOK
OFFICE OF SALINE WATER
OSW 10.154
DATE 12-63

CALCIUM CARBONATE IN CONCENTRATED SEA WATER

STABILITY DIAGRAM





NOTES:

1. SEE SHEET OSW 10.150 FOR A DISCUSSION ON THE USE OF THIS CHART.
2. THIS CHART IS DESIGNED FOR CONCENTRATED SEA WATER HAVING A TOTAL MINERAL CONTENT BETWEEN 25,000 AND 100,000 MG PER LITER. CHART MAY ALSO BE USED FOR SIMILAR SALINE WATERS (HARBOR WATERS, ETC.) PROVIDING THE TOTAL ALKALINITY IS DUE ONLY TO BICARBONATE.

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U.S. DEPT. OF THE INTERIOR
UNDER CONTRACT NO. 14-01-0001-291

ILLUSTRATION

ASSUME: Ca = 2,000, TOTAL ALKALINITY = 100 (BOTH EXPRESSED AS ppm EQUIVALENT $CaCO_3$); pH (AT 77°F) = 8.6. FIND THE SATURATION pH AND SATURATION INDEX AT 212°F.

SOLUTION: REFERRING TO THE 212°F CHART, LOCATE INTERSECTION OF Ca = 2,000 AND TOTAL ALKALINITY = 100. READ pH$_S$ = 7.0. SATURATION INDEX = 8.6 − 7.0 = 1.6.

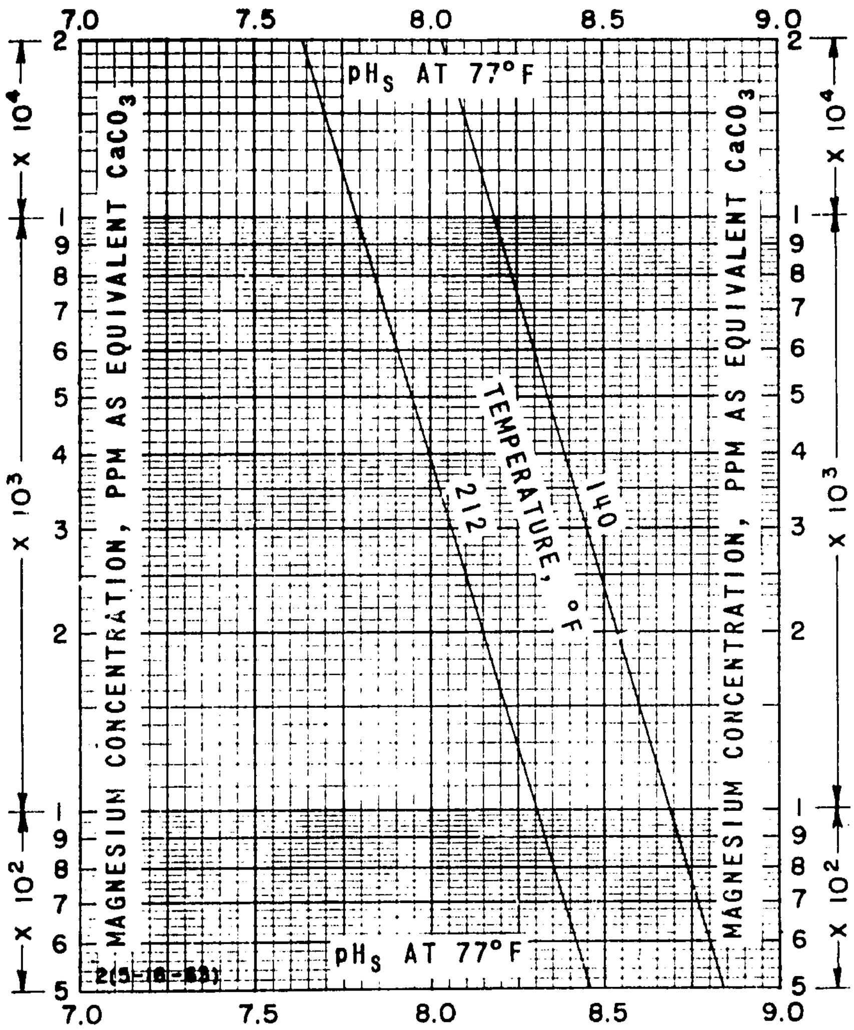
TECHNICAL DATA BOOK
OFFICE OF SALINE WATER
CURVE OSW 11.151
W.C.S. DATE 5-63

REFERENCE:

Langelier, W.F., Caldwell, D.H., and Lawrence, W.B., *Causes and Preventives of Scale and Corrosion in Thermocompression Equipment when Employed for the Distillation of Sea Water*, Inst. Engg. Research Report, Univ. of California, Berkeley, Calif. (August 15, 1950).

MAGNESIUM HYDROXIDE IN CONCENTRATED SEA WATER

STABILITY DIAGRAM



NOTES:

1. SEE SHEET OSW 10.150 FOR A DISCUSSION ON THE USE OF THIS CHART.
2. THIS CHART IS DESIGNED FOR CONCENTRATED SEA WATER HAVING A TOTAL MINERAL CONTENT BETWEEN 25,000 AND 100,000 MG PER LITER. CHART MAY ALSO BE USED FOR SIMILAR SALINE WATERS (HARBOR WATERS, ETC.) PROVIDING THE TOTAL ALKALINITY IS DUE ONLY TO BICARBONATE.

REFERENCE:

Langelier, W.F., Caldwell, D.H., and Lawrence, W.B., *Causes and Preventives of Scale and Corrosion in Thermocompression Equipment when Employed for the Distillation of Sea Water*, Inst. Engg. Research Report, Univ. of California, Berkeley, Calif. (August 15, 1950).

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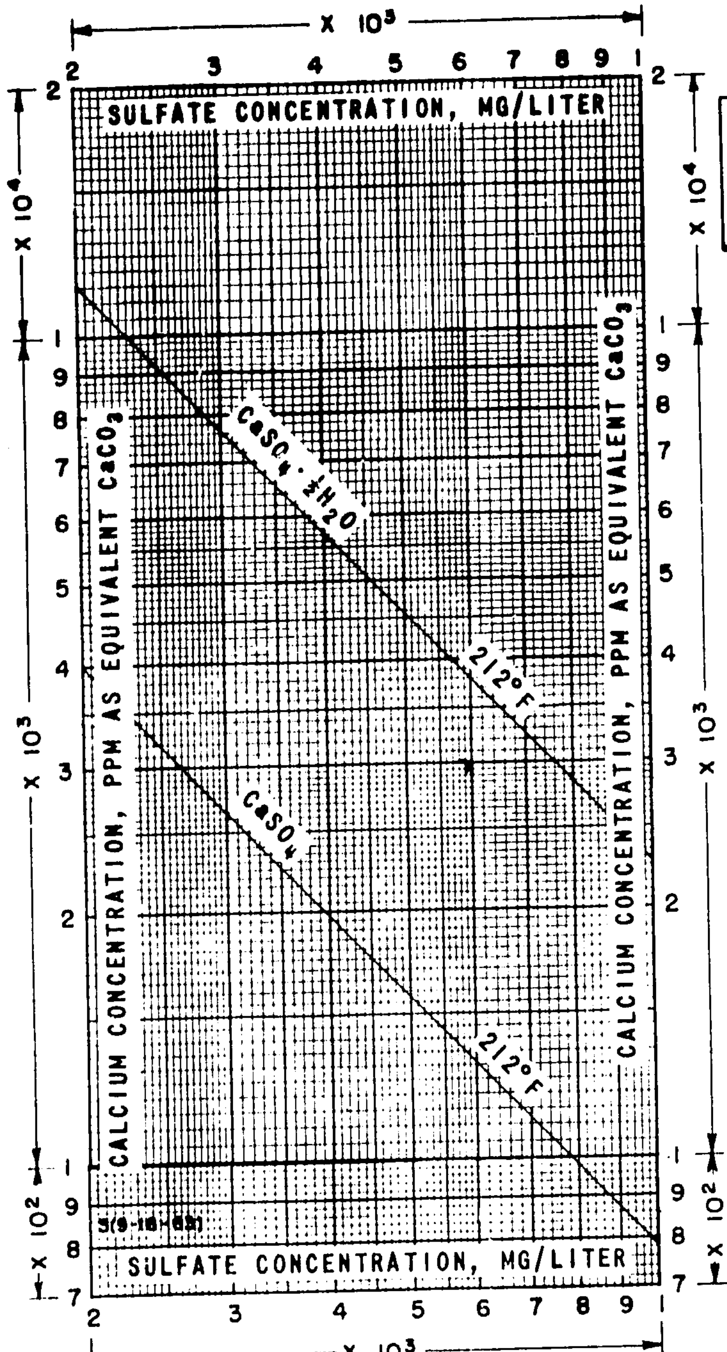
THE M.W. KELLOGG CO.
FOR THE OFFICE OF SALINE WATER
U.S. DEPT. OF THE INTERIOR
UNDER CONTRACT NO. 14-01-0001-291

ILLUSTRATION

ASSUME: Mg = 10,000 PPM AS EQUIVALENT $CaCO_3$, AND pH (AT 77°F) = 8.6. FIND THE SATURATION pH AND SATURATION INDEX WITH RESPECT TO MAGNESIUM HYDROXIDE AT 212°F.

SOLUTION: LOCATE INTERSECTION OF Mg = 10,000 AND THE 212°F CURVE. READ pH_S = 7.8. SATURATION INDEX = 8.6 - 7.8 = 0.

TECHNICAL DATA BOOK
OFFICE OF SALINE WATER
CURVE OSW 11.152
APPROVED W.C.S. DATE 5-63



CALCIUM SULFATE IN CONCENTRATED SEA WATER

STABILITY DIAGRAM

NOTES:

1. SEE SHEET OSW 10.150 FOR A DISCUSSION ON THE USE OF THIS CHART.
2. THIS CHART IS DESIGNED FOR CONCENTRATED SEA WATER HAVING A TOTAL MINERAL CONTENT BETWEEN 25,000 AND 100,000 MG PER LITER. CHART MAY ALSO BE USED FOR SIMILAR SALINE WATERS (HARBOR WATERS, ETC.) PROVIDING THE TOTAL ALKALINITY IS DUE ONLY TO BICARBONATE.

REFERENCE:

Langelier, W.F., Caldwell, D.H., and Lawrence, W.B., *Causes and Preventives of Scale and Corrosion in Thermocompression Equipment when Employed for the Distillation of Sea Water,* Inst. Engg. Research Report, Univ. of California, Berkeley, Calif. (August 15, 1950).

ILLUSTRATION

ASSUME: SULFATE CONCENTRATION = 6,000 MG PER LITER. Ca CONCENTRATION = 3,000 PPM, AS EQUIVALENT $CaCO_3$. DETERMINE WHETHER SOLUTION IS SATURATED AT 212°F.

SOLUTION: PLOTTING THE POINT Ca = 3,000 AND SO_4 = 6,000, WE NOTE THAT THE POINT FALLS TO THE RIGHT OF THE $CaSO_4$ LINE, BUT TO THE LEFT OF THE $CaSO_4 \cdot \frac{1}{2}H_2O$ LINE. HENCE, THE SOLUTION IS SUPERSATURATED WITH $CaSO_4$, BUT NOT WITH $CaSO_4 \cdot \frac{1}{2}H_2O$.

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FOR THE OFFICE OF SALINE WATER
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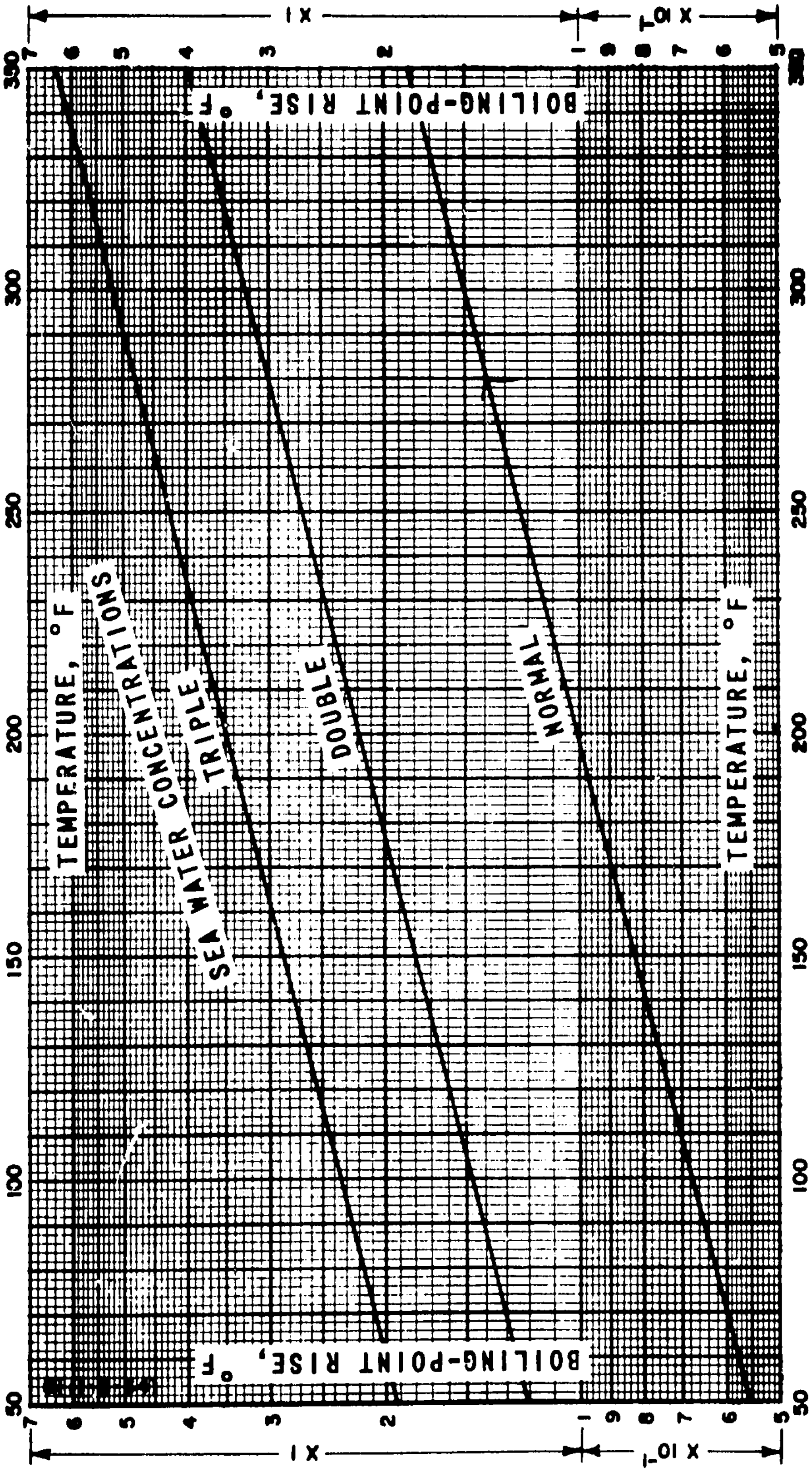
UNDER CONTRACT NO. 14-01-0001-291

TECHNICAL DATA BOOK
OFFICE OF SALINE WATER
CURVE OSW 11.153
W.C.S. DATE 9-63

SEA WATER

BOILING–POINT RISE



NOTE:

THE NORMAL SEA WATER CONCENTRATION USED IN THIS CHART HAS 34.483 G SOLIDS PER 1000 G SEA WATER.

REFERENCES:

1. Frankel, A., *Proc. Inst. Mech. Engrs. (London)*, 174, 312 (1960).
2. U.S. Dept. of the Interior, Saline Water Research and Development Progress Report No. 12, p. 70 (Nov. 1956).

THIS CHART PREPARED BY
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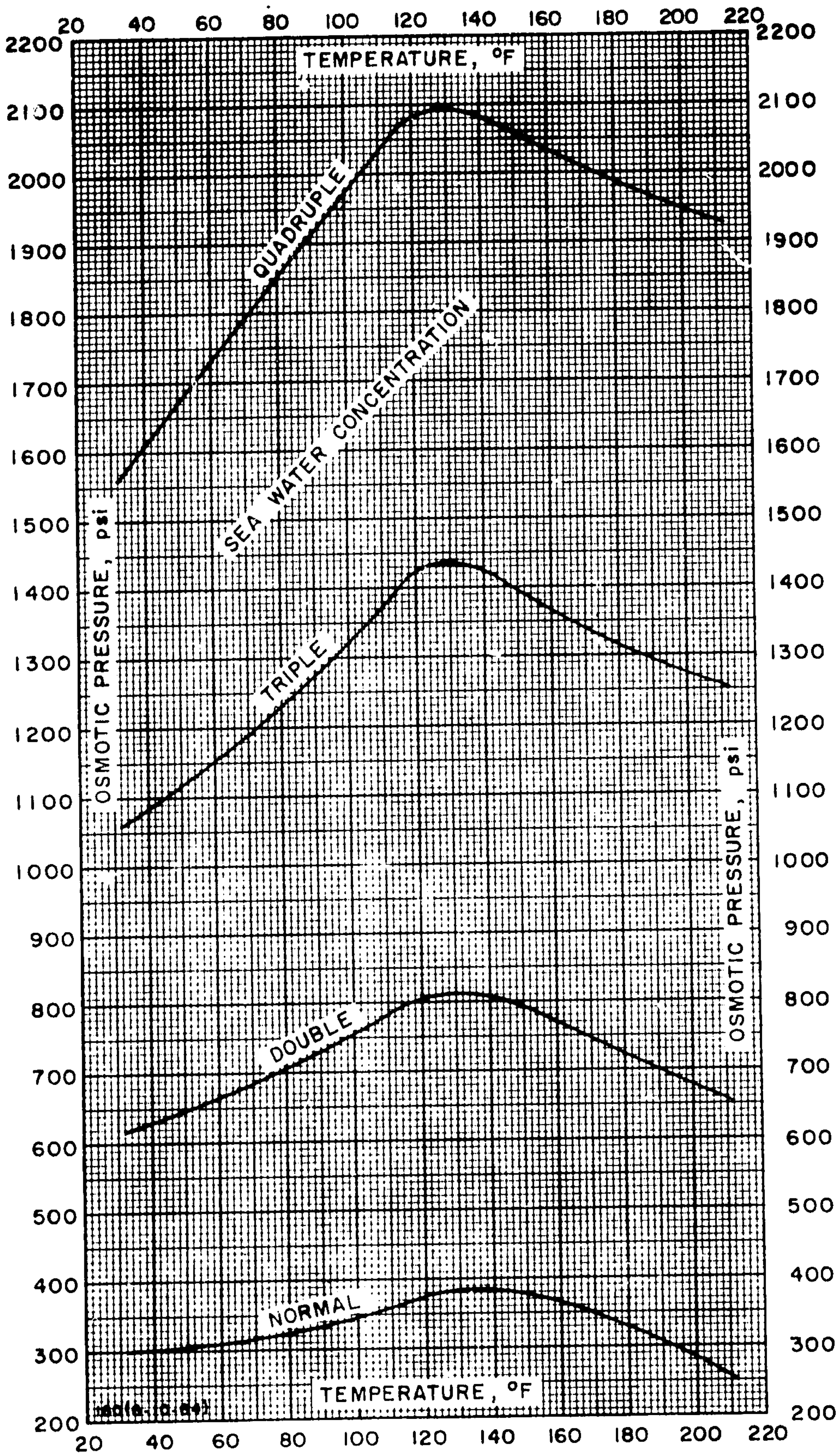
UNDER CONTRACT NO. 14-01-0001-357

SEA WATER
OSMOTIC PRESSURE



NOTE:
THE NORMAL SEA WATER CONCENTRATION USED IN THIS CHART HAS 34.483 G SOLIDS PER 1,000 G SEA WATER.

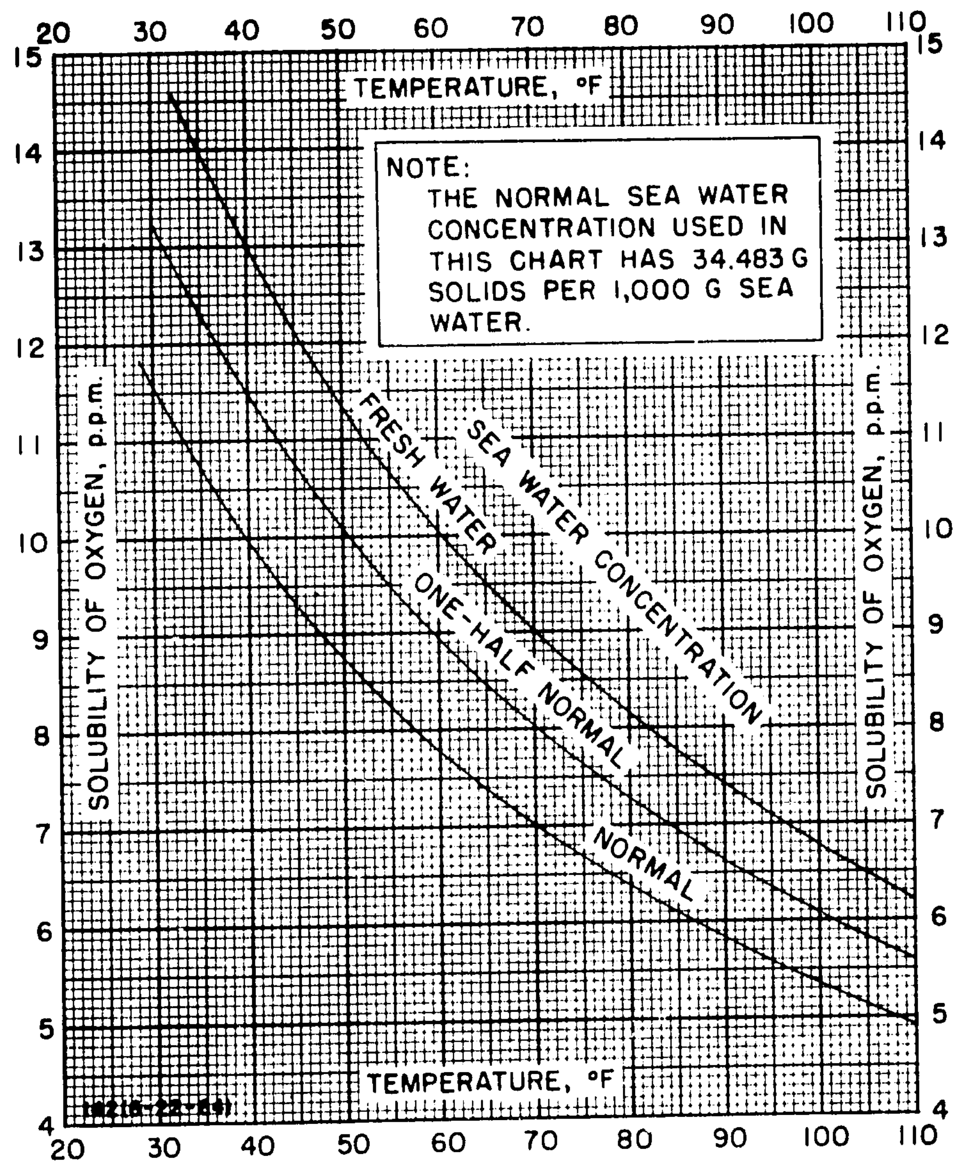
THIS CHART PREPARED BY THE M. W. KELLOGG CO FOR THE OFFICE OF SALINE WATER U.S. DEPT OF THE INTERIOR UNDER CONTRACT NO 14-01-0001-357

REFERENCE:

Tribus, M., *et al.*, Report No 59-34: *Thermodynamic and Economic Considerations in the Preparation of Fresh Water from Sea Water*, p. II-34, Univ Calif. Dept. of Engg., Los Angeles, Calif. (Sept. 1960).

SEA WATER
SOLUBILITY OF OXYGEN

(OXYGEN DISSOLVED IN SEA WATER IN EQUILIBRIUM WITH WATER VAPOR SATURATED AIR AT ONE ATMOSPHERE PRESSURE)



THIS CHART PREPARED BY
THE M. W. KELLOGG CO.
FOR THE OFFICE OF SALINE WATER
U.S. DEPT OF THE INTERIOR
UNDER CONTRACT NO 14-01-0001-357

REFERENCES:

1. Redfield, A.C., *Characteristics of Sea Water*, p. 7, Woods Hole Oceanographic Institution, Woods Hole, Mass. (undated).
2. Truesdale, G.A., and Gameson, A.L.H., *J. Conseil, Conseil Perm. Intern. Exploration Mer*, 22, 163 (1957).

TECHNICAL DATA BOOK
OFFICE OF SALINE WATER
CURVE OSW 11.581
DATE 6-64

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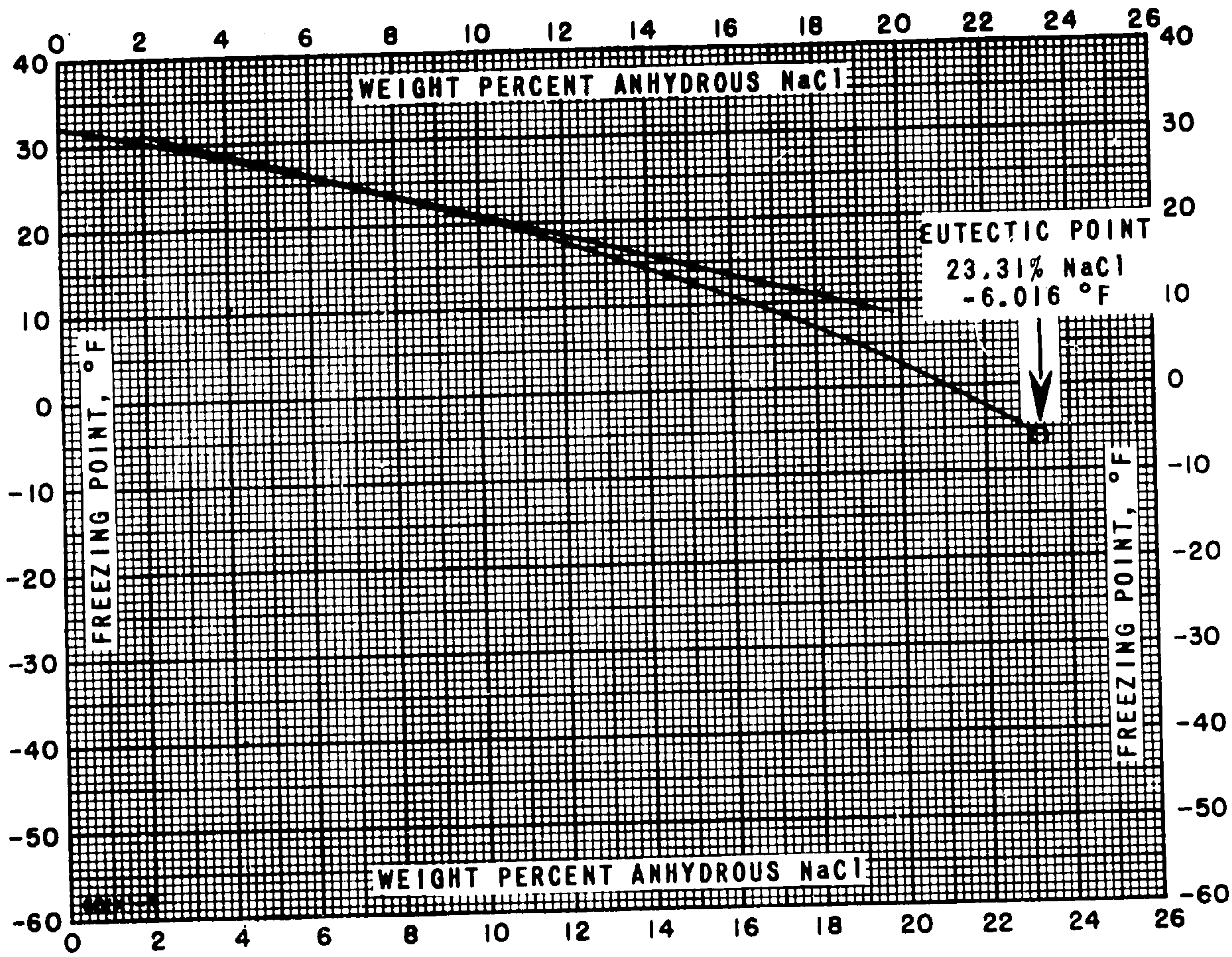
UNDER CONTRACT NO. 14-01-0001-291

FREEZING POINTS OF AQUEOUS SODIUM CHLORIDE SOLUTIONS



REFERENCES:

1. Jessup, R.S., *Refrig. Eng.*, 22, 168 (1931).
2. Kaufmann, D.W., *Sodium Chloride*, p. 613, Reinhold Publishing Corp., New York (1960).

THE USE OF ENTHALPY CHARTS IN THE CALCULATION OF HEAT AND MATERIAL BALANCES

Fresh water may be obtained from sea water by evaporation from the sea water, after which concentrated saline solution is discharged. Such a system is shown diagrammatically in Figure 1, wherein evaporation is effected by means of condensing steam in a coil, tube bank, or other suitable structure. The solution of a sample problem in which a steam rate is to be determined is illustrated.

The overall heat and mass balances for the depicted system will be set by certain fixed or required conditions, which in this case are set as:

1) System pressure = 14.7 psia
2) Fresh brine rate = 1000 gph
3) Fresh brine chlorinity = 19.0
4) Spent brine chlorinity = 100.0
5) Available steam pressure = 25.0 psia
6) Fresh brine temperature = 80°F

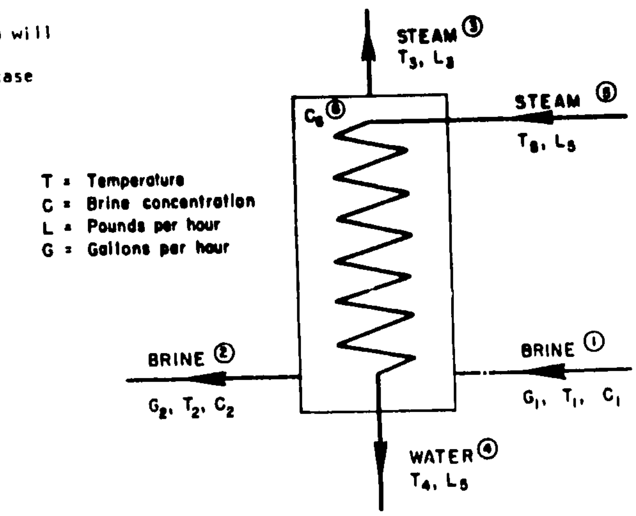


FIGURE 1

The following calculation then illustrates the derivation of overall heat and material balances:

Concentration C_1 is equivalent to 3.44 wt. % NaCl (OSW 0.021)

Concentration C_2 is equivalent to 18.0 wt. % NaCl (OSW 0.021)

Concentration C_6 is equivalent to 18.0 wt. % NaCl.

Since the system pressure = 14.7 psia,

Temperature T_3 = 220°F (OSW 12.50)

Temperature T_2 = 220°F (OSW 12.50)

Density of Stream 1 = 63.7 lbs/cu ft. (OSW 12.60)

Therefore, mass flow rate of Stream 1 = 8,510 lbs/hr

Therefore, by mass balance, $0.18\ L_2 = 0.0344\ L_1$

Therefore L_2 = 1,630 lbs/hr

and L_3 = 6,880 lbs/hr.

Enthalpy of Stream 1 = 248 Btu/lb (OSW 12.30)

Enthalpy of Stream 2 = 363 Btu/lb (OSW 12.30)

Enthalpy of Stream 3 = 1153 Btu/lb (OSW 10.31)

Enthalpy of Stream 4 = 208 Btu/lb (OSW 10.31)

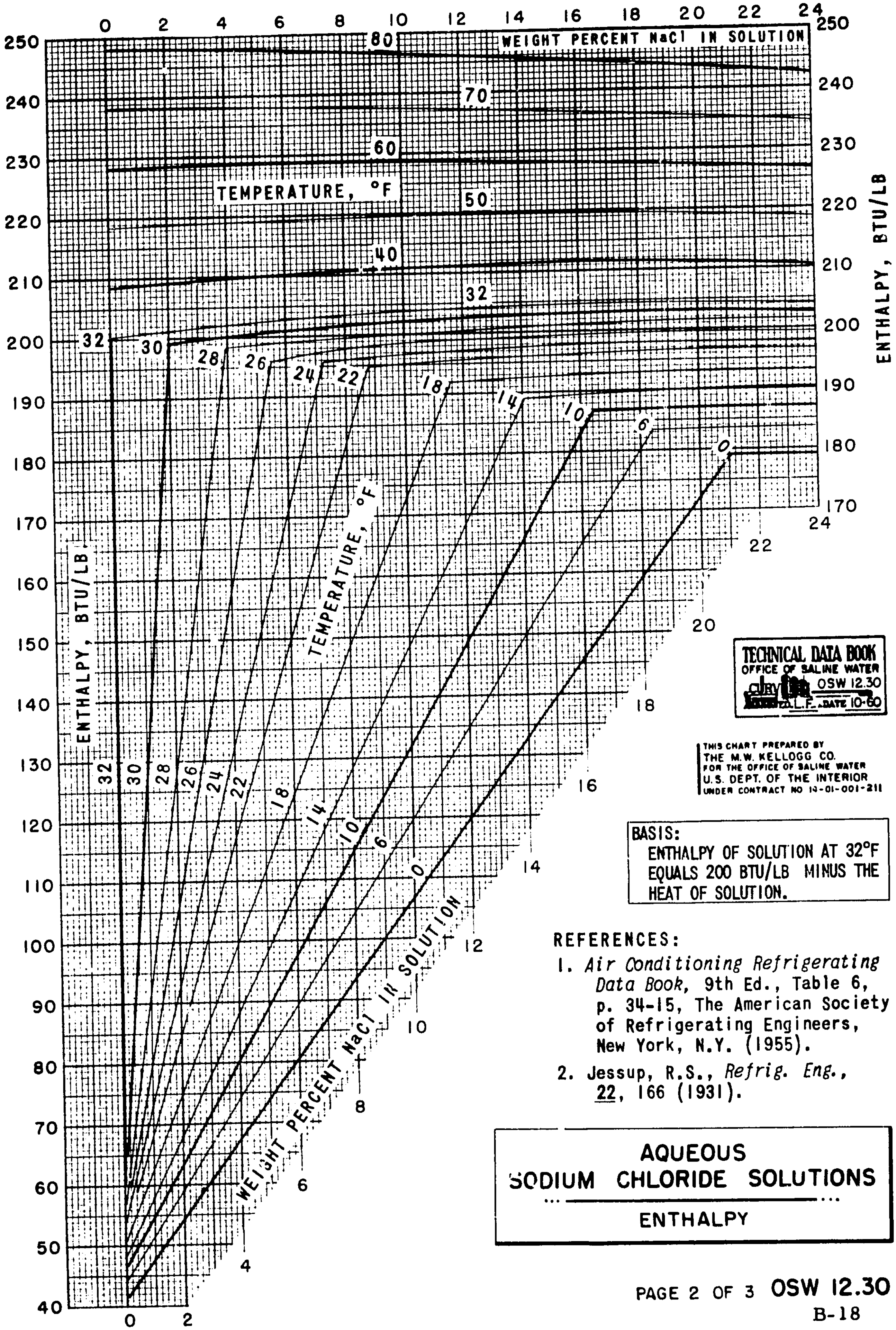
Enthalpy of Stream 5 = 1161 Btu/lb (OSW 10.31)

Therefore, by enthalpy balance,

$$L_5 \times 1161 + 8510 \times 248 = 1630 \times 363 + 6880 \times 1153 + L_5 \times 208$$

from which the steam rate = 6,730 lbs/hr.

THIS SHEET PREPARED BY
THE M. W. KELLOGG CO.
FOR THE OFFICE OF SALINE WATER
U. S. DEPT. OF THE INTERIOR
UNDER CONTRACT NO. 14-01-0001-357



TECHNICAL DATA BOOK
OFFICE OF SALINE WATER
OSW 12.30
DATE 10-60

THIS CHART PREPARED BY
THE M.W. KELLOGG CO.
FOR THE OFFICE OF SALINE WATER
U.S. DEPT. OF THE INTERIOR
UNDER CONTRACT NO 14-01-001-211

BASIS:
ENTHALPY OF SOLUTION AT 32°F EQUALS 200 BTU/LB MINUS THE HEAT OF SOLUTION.

REFERENCES:

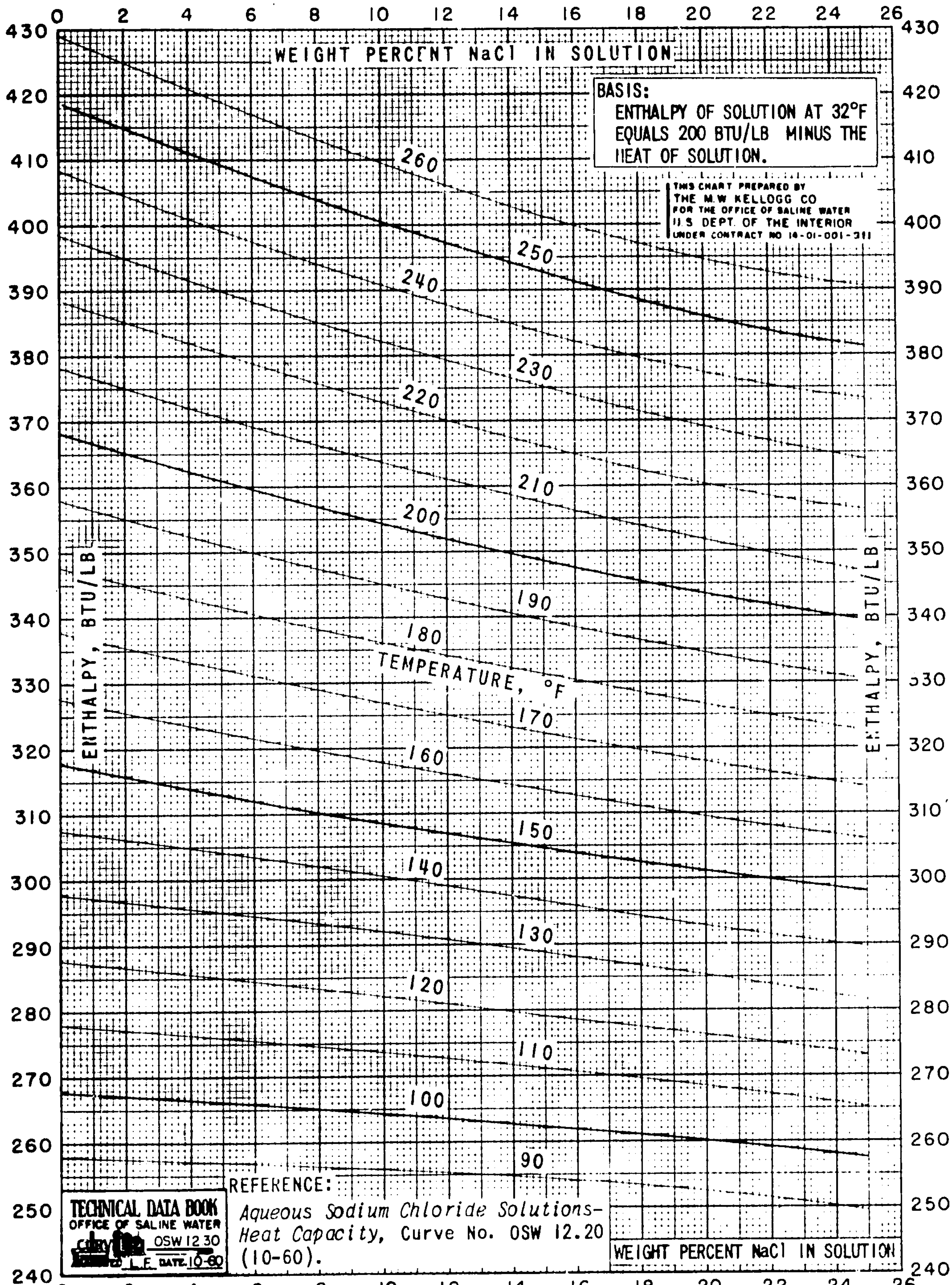
1. *Air Conditioning Refrigerating Data Book*, 9th Ed., Table 6, p. 34-15, The American Society of Refrigerating Engineers, New York, N.Y. (1955).
2. Jessup, R.S., *Refrig. Eng.*, 22, 166 (1931).

AQUEOUS SODIUM CHLORIDE SOLUTIONS

ENTHALPY

AQUEOUS SODIUM CHLORIDE SOLUTIONS

ENTHALPY



APPENDIX C

This appendix includes estimating aids and nomographs for determining capital costs of desalination plant facilities.

ESTIMATING AIDS

Capital costs of possible natural freshwater facilities can be made by engineers experienced in similar construction projects. Because of the limited experience in construction of desalination facilities, however, it may be more difficult to secure rough estimates for desalination. In such cases the following procedure and accompanying notes and nomographs (found at the end of this appendix) may be utilized to determine approximate capital costs and unit costs of water for seawater desalination facilities under conditions which will be used in the preliminary feasibility studies.

Most of the seawater desalination plants built or proposed in the past several years have utilized the multistage flash evaporation process and were designed for a top brine temperature of 200F to 250F. Other leading seawater desalination processes, however, have capital and operating costs generally comparable to those of the multistage flash plants. Therefore, while the Unit Desalination Plant Capital Cost Nomograph is based on multistage flash evaporator plants, it may be utilized for other leading seawater desalination cost approximations.

Estimating aids for brackish water desalination facilities have not been included, as the variation in costs due to local water conditions requires a more detailed approach; however, a listing of typical costs of electrodialysis plants ranging in nominal capacity from 250,000 to 2,500,000 gpd is shown in Table C-5. It should be noted that this table is based on plants using Webster, South Dakota water which has a salinity of approximately 1,400 ppm and a product water salinity of approximately 500 ppm. This 60% reduction in salinity required 3 stages. A more saline brackish water supply or a less saline product water requirement would require more stages and, therefore, a more costly installation.

Since seawater desalination processes may be utilized on brackish water sources, the seawater desalination costs may be used as the upper limit of the costs of brackish water desalination.

DESALINATION FACILITY CAPITAL COSTS

The first step in preparing the capital cost approximations is to establish the following preliminary design conditions (Notes 1 and 2 at the end of this appendix may be useful in establishing these values):

1. Plant capacity in gallons per day (gpd) -- see Note 1, C-5.

2. Plant operating factor -- see Note 1.

3. Economy ratio -- see Note 2, C-5

Having selected the nominal plant capacity, the plant operating factor and several economy ratios (in accordance with the preliminary feasibility study requirements and the corresponding notes), one may begin the determination of the estimated desalination facility capital cost. This is accomplished in the following manner:

1. Determine the unit desalination plant capital cost for each economy ratio by utilizing the Unit Desalination Plant Capital Cost Nomograph, Figure C-1.

2. Determine the desalination plant capital cost for each economy ratio by multiplying the unit desalination plant capital cost determined above by the nominal plant capacity. Tabulate the results in Table C-1 below.

3. Determine and tabulate the heat source capital cost for each economy ratio, as described in Note 3, page C-6.

4. Determine and tabulate the product water conveyance capital cost, as described in Note 4, page C-6.

5. Determine and tabulate the land capital cost, as described in Note 5, page C 6.

6. Determine and tabulate the other capital costs and contingency, as described in Note 6, page C-7.

7. Complete Table C-1 and determine the unit facility capital cost by dividing the total desalination facility capital cost by the nominal plant capacity.

For examples, see Table C-3, page C-8.

TABLE C-1

DESALINATION FACILITY CAPITAL COST

Economy ratio				
Desalination plant capital cost				
Heat source capital cost				
Product water conveyance capital cost				
Land capital cost				
Subtotal				
Other capital costs and contingency				
Total Desalination Facility Capital Cost				
Unit facility capital cost, $ per daily gallon				

UNIT COST OF WATER

Before utilizing the nomographs and notes (at the end of this appendix) to estimate the unit cost of water, it is necessary to establish the following preliminary feasibility study conditions:

1. Fixed charge rate -- see Note 7, C-7.

2. Unit cost of fuel -- see Note 8, C-9.

3. Hourly labor cost -- see Note 9, C-10.

4. Chemicals and other costs -- see Note 10, C-10.

Having determined the fixed charge rate, the unit cost of fuel and the hourly labor cost, the estimating of the unit cost of water may be accomplished in the following manner:

1. Determine, and tabulate below, the fixed cost component (for each economy ratio) by utilizing the Fixed Cost Component Nomograph, Figure C-2.

2. Determine, and tabulate below, the fuel cost component (for each economy ratio) by utilizing the Fuel Cost Component Nomograph, Figure C-3.

3. Determine, and tabulate below, the labor cost component by utilizing the Labor Cost Component Nomograph, Figure C-4.

4. Determine, and tabulate below, the chemical and other unit costs, as described in Note 10.

5. Total the above to determine the unit cost of water. The economy ratio that results in the lowest unit cost of water will then be evident.

TABLE C-2

UNIT COST OF WATER

Economy ratio				
Fixed cost component	______	______	______	______
Fuel cost component	______	______	______	______
Labor cost component	______	______	______	______
Chemical and other unit costs	______	______	______	______
Total Unit Cost of Water	______	______	______	______

Note: The above approximations used in determining the unit cost of water treat the nondepreciable items of land and working capital as though they were depreciable items, whereas a lower fixed charge rate (excluding depreciation and insurance) should be used on these items. This error, however, is small in relation to the other uncertainties of this estimate.

NOTES AND NOMOGRAPHS

Note 1 - Nominal Plant Capacity and Plant Operating Factor

The nominal plant capacity is usually expressed in gallons per day--the amount of product water that will be produced when the plant is running at design conditions. Every desalination plant, however, must be shut down occasionally for preventive maintenance and for repair of tube leaks and other unscheduled outages. The water that a plant can be expected to produce each year is not 365 times its design daily capacity, but is some factor (less than 1) multiplied by 365 times its design daily capacity. This factor is the plant operating factor, which is defined as the ratio of actual annual water production to the quantity of water that could be produced annually if the plant were operated continuously at full rated output. The plant operating factor usually is expressed as a percentage value. A plant operating factor of 90% has been assumed to be achievable in some feasibility studies for single-purpose plants.

Therefore, the nominal plant capacity should be selected to secure the required annual product water production with a reasonable plant operating factor (usually 90% for single-purpose plants or 80% to 85% for dual-purpose electric-power water-desalination plants).

The Unit Desalination Plant Capital Cost Nomograph is based on desalination plants consisting of only one module (module capacity and nominal capacity are the same). When plants of several modules are being considered, the unit desalination plant capital cost and the desalination plant capital cost should be determined for each module (by using module capacity for nominal capacity). The sum of the capital costs of the modules should be used as the desalination plant capital cost in Table C-1.

Note 2 - Economy Ratio

Seawater distillation plants require saturated steam at approximately 25 psig. (Low cost steam to as low a pressure as 10 psig may be utilized with only a small increase in desalination plant capital cost.) One measure of plant performance is the economy ratio--defined as the pounds of product water produced per pound of steam supplied to the plant. The appropriate economy ratio to use in the plant design must be determined by optimizing the design for lowest unit water cost. For low unit cost of fuel and relatively high fixed charge rates, a low economy ratio (4 to 6) may be optimum. For high fuel costs and low fixed charges, a higher economy ratio may be optimum.

The nomographs may be used as a means of approximating the optimum economy ratio by selecting a value (usually about 8) and performing the necessary calculations to determine the unit cost of water. Then, values of economy ratio higher and lower than 8, say 6 and 10, should be selected and the new unit cost of water determined for each. These calculations should be continued until an economy ratio is found that results in the lowest unit cost of water.

Note 3 - Heat Source Capital Cost

The approximate capital cost of an oil or gas fired boiler may be determined by the following empirical equation:

$$\text{Heat source capital cost} = 0.55^{*} \times \frac{\text{nominal plant capacity (gpd)}}{\text{economy ratio}}$$

*An empirical value determined by boiler cost-capacity correlations.

Note 4 - Product Water Conveyance Capital Cost

To determine the approximate capital cost of the product water conveyance, determine the miles of conveyance required and multiply by the typical cost per mile, from the table below.

Nominal Plant Capacity, gpd	Pipe Diameter, Inch	Typical Cost/Mile
100,000	4	$ 6,500
200,000	6	18,000
300,000	8	22,000
500,000	8	22,000
1,000,000	10	27,000
2,000,000	12	32,000
3,000,000	16	43,000
4,000,000	20	57,000
5,000,000	20	57,000
7,500,000	24	71,000
10,000,000	24	71,000

Note 5 - Land Cost

The desalination plant capital cost estimates determined by use of the nomograph include typical cost of on-site improvements such as surveys, roadways and paved areas but excludes land cost.

The land required to accommodate a desalination facility of 1 million gpd capacity is approximately 2 acres. For a desalination plant facility of 10 million gpd approximately 10 acres are required. In addition to the cost of the land itself, the land cost should include allowance for site access and such costs as surveys, right of ways, access roadways, and unusual site development work. Since these capital costs vary greatly with location and site conditions, estimates should be prepared by those familiar with the proposed site and with local site development costs.

Note 6 - Other Capital Costs and Contingency

Other costs required to construct and operate a desalination facility are:

a. The cost of engineering, design, inspection and procurement

b. The owner's expenses prior to commercial operation of the facility including start-up

c. Interest during construction

d. Working capital including allowances for inventory costs of fuel, chemicals, materials, and supplies; for insurance prepayment, for spare parts inventory and for accounts receivable.

While the nomograph used in estimating the desalination plant capital cost is based on actual plants and estimates of proposed plants, which may in some cases include contingency, it is appropriate to include a contingency in this cost estimate as well.

To provide an allowance for other costs and contingency, a percentage of the cost of the desalination facility may be used. A value of 20% of the cost estimate of the desalination facility (sum of desalination plant capital cost, heat source capital cost, product water conveyance capital cost and land capital cost) is recommended as the allowance for other capital costs and contingency.

Note 7 - Fixed Charge Rate

Whenever possible, the fixed charge rate on capital investment should be based on factual information for the specific project. For study evaluations and projects on which the actual fixed charge rate is not available, a fixed charge rate may be developed by the method outlined below.

The fixed charge rate on depreciable capital comprises the following elements:

a. Interest charges

b. Depreciation

c. Interim replacements

d. Property insurance

e. Federal income taxes (none in the case of a municipal utility)

f. State and local taxes

In the case of a utility operated by a government entity, the interest charges would be representative of the interest rate at which bonds could be sold by that government agency. Once the interest rate and plant life is known, the depreciation can be determined. Table C-3 gives the sinking fund depreciation for different interest rates and depreciation periods. For depreciable capital, the sum of the interest rate plus depreciation is the amortization rate that will recover the capital investment over the depreciation period. Note that in the case of nondepreciable capital, such as land and working capital, no depreciation or interim replacement is applied and insurance is applied only to inventory items such as spare parts.

TABLE C-3

ANNUAL SINKING FUND DEPRECIATION FOR DIFFERENT PERIODS (YEARS)

Interest Rate, %/Yr	10 Yr	15 Yr	20 Yr	25 Yr	30 Yr	35 Yr	40 Yr
2	9.13	5.78	4.12	3.12	2.46	2.00	1.66
3	8.72	5.37	3.72	2.74	2.10	1.65	1.32
4	8.33	4.99	3.35	2.40	1.78	1.38	1.05
5	7.95	4.63	3.02	2.10	1.51	1.11	0.83
6	7.59	4.30	2.72	1.82	1.26	0.90	0.65
7	7.24	3.98	2.44	1.58	1.06	0.72	0.50
8	6.90	3.68	2.19	1.37	0.88	0.58	0.39

For a detailed engineering study of a proposed desalination plant, the allowance for interim replacements of tubes and other plant components may be based on a detailed projection of tube failure rates (for a distillation plant) as a function of plant life. Lacking such a detailed analysis, a value of 1% may be added to the fixed charge rate to allow for interim replacement. This value is approximately correct for a 15-year tube life and a 30-year plant life. It should be noted that interim replacements are sometimes included as an operating cost element, rather than as a component of fixed charges for the approximate cost estimates outlined herein.

Annual property insurance cost may be taken as 0.2% of the depreciable capital cost--this is a typical average value for utilities such as fossil-fueled power plants.

A municipally-owned utility does not pay federal income taxes but may incur state and local taxes, or costs in lieu of local taxes.

Tabulated below is a typical breakdown of fixed charge rates for a municipally-owned utility, assuming 4% interest rate and a 30-year plant life.

	Depreciable Capital, %	Nondepreciable Capital, %
Interest charges	4.0	4.0
Depreciation (30-year sinking fund basis)	1.8	-
Interim replacements	1.0	-
Insurance, property	0.2	-
State and local taxes (or costs in lieu of local taxes)	1.4	1.4
Total Fixed Charge Rate	8.4%	5.4%

Note 8 - Unit Cost of Fuel

The unit cost of fuel (oil or gas) is the cost (in cents per million Btu--higher heating value) at the plant site. The unit cost should include transportation and unloading costs and demand charges.

Note 9 - Hourly Labor Cost

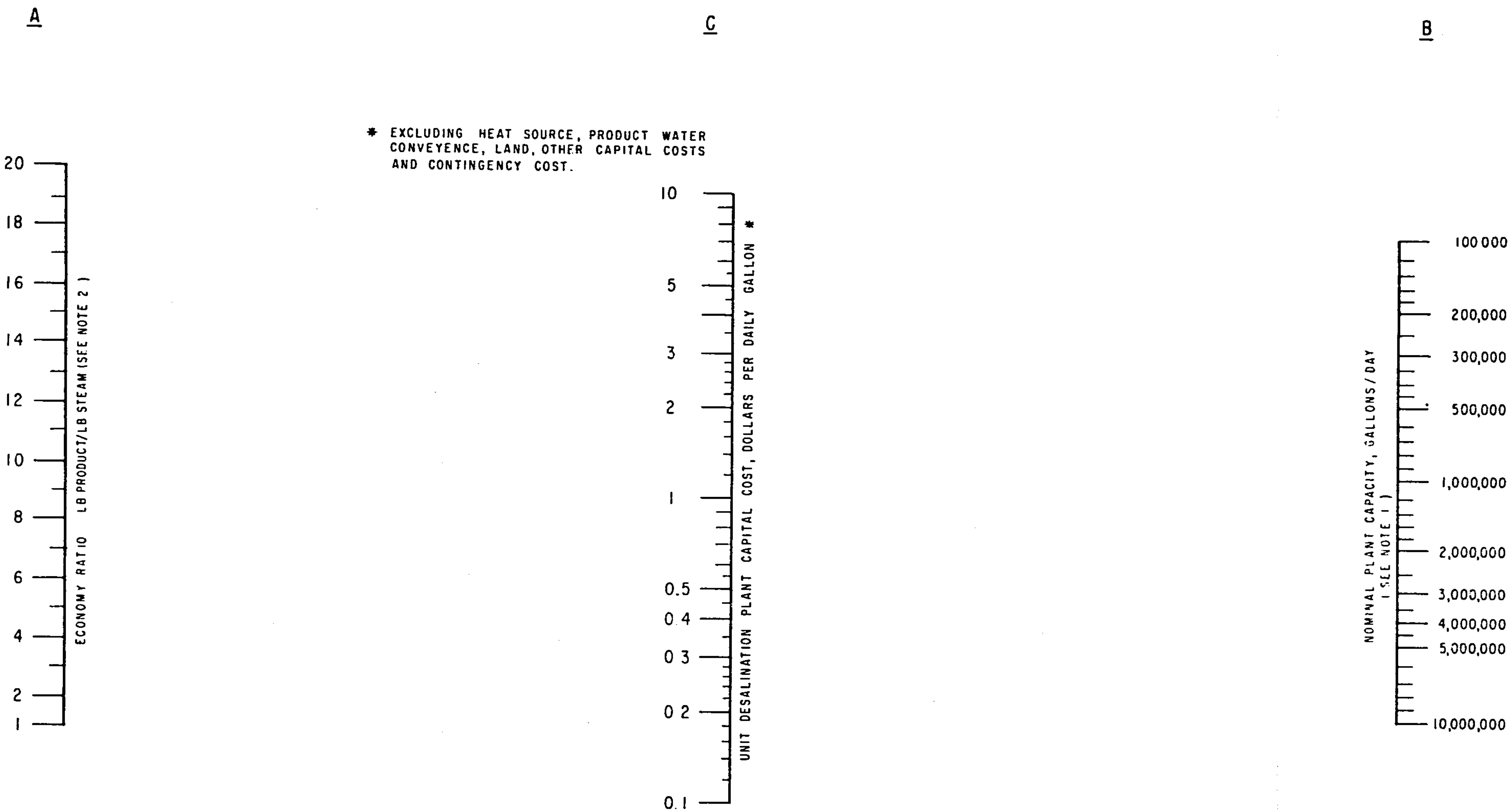
The hourly labor cost is the wages paid each hour to the plant staff plus allowance for overhead and for general and administrative expenses. Because the day shift may include an operator and several maintenance men, whereas the night shifts may have only operators, the wages should be determined by dividing the weekly or monthly total wages (including overhead and general and administrative expense) by the total hours in the same period.

Note 10 - Chemicals and Other Unit Costs

The chemicals required for a seawater desalination facility include H_2SO_4, chlorine and caustic. The other unit costs include electric power for pumps, instruments and lighting. An allowance of $0.08 per 1,000 gallons should be made for the chemical and other unit costs.

FIGURE C - 1

UNIT DESALINATION PLANT CAPITAL COST NOMOGRAPH

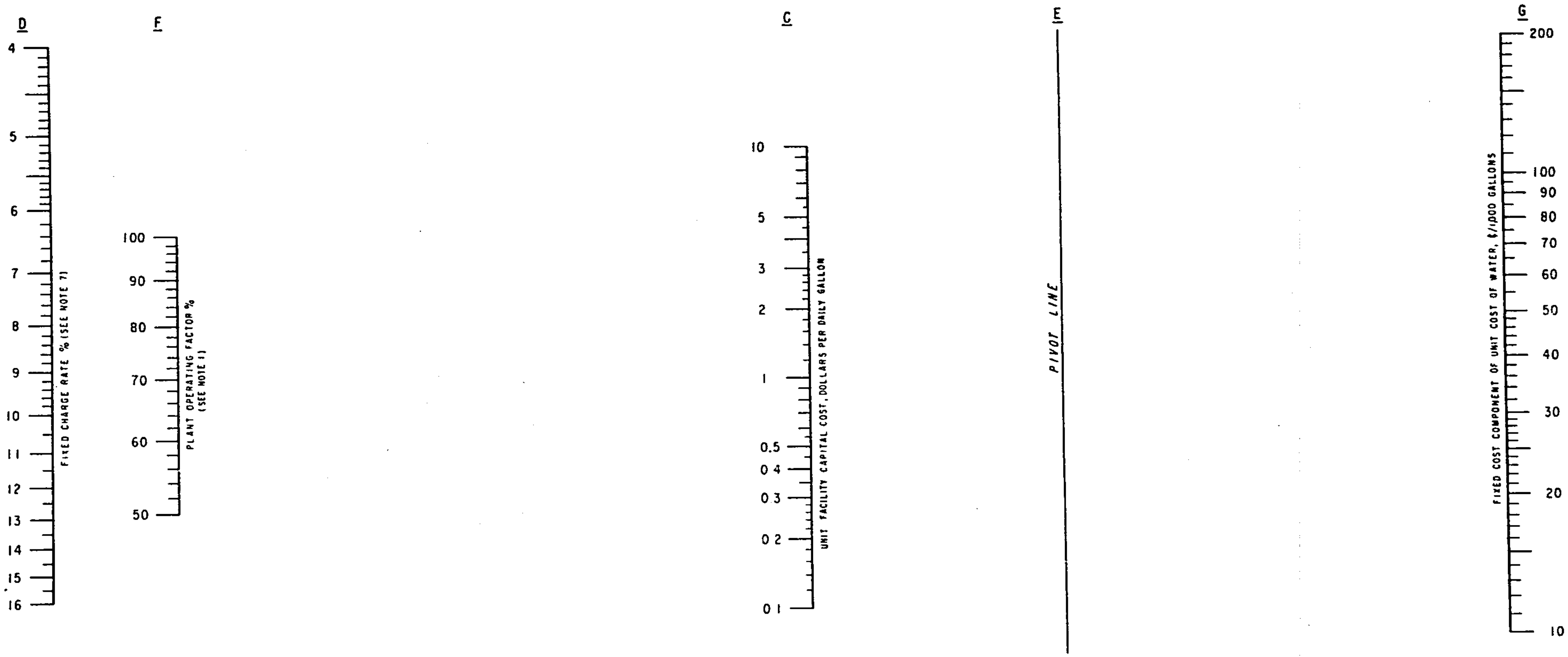


1. Connect the selected economy ratio on Scale A and nominal plant capacity on Scale B by a straight line, and note where this line crosses Scale C.

2. To obtain the desalination plant capital cost, multiply the unit capital cost value noted on Scale C by the nominal plant capacity (gpd), and record it in Table C-1. Desalination Facility Capital Cost.

FIGURE C - 2

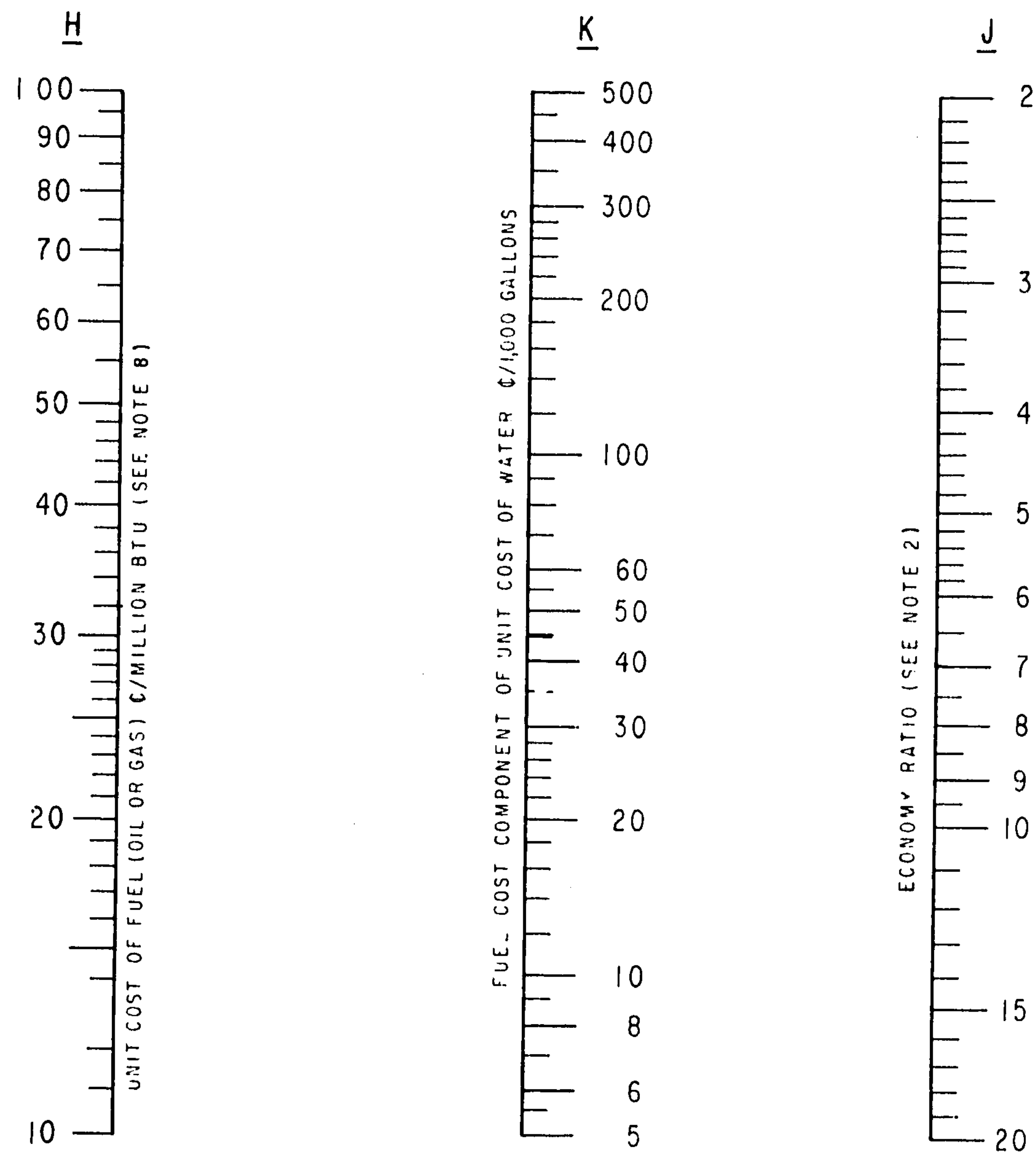
FIXED COST COMPONENT NOMOGRAPH



1. Draw a straight line from the unit facility capital cost (as determined in Table C-1) on Scale C to the fixed charge rate on Scale D and note where the extension of this line crosses the pivot line E.
2. Draw a straight line from the plant operating factor on Scale F through the point on the pivot line on Scale E and note where Scale G is crossed
3. Read the value of the fixed cost component on Scale G and record it in Table C-2, Unit Cost of Water

FIGURE C - 3

FUEL COST NOMOGRAPH

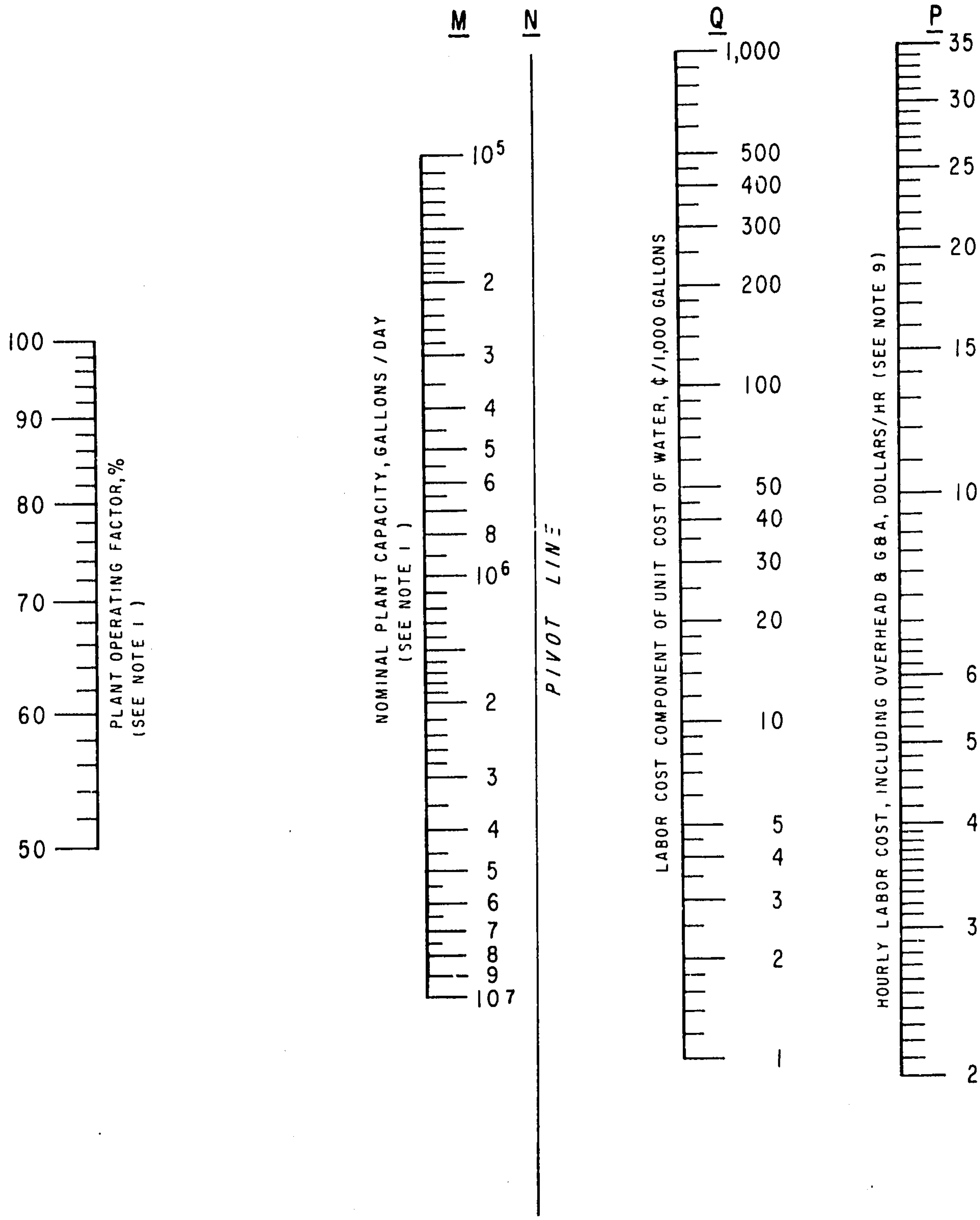


1. Draw a straight line from the unit cost of fuel on Scale H to the economy ratio on Scale J, and note the crossing of Scale K--fuel cost component of unit cost of water.

2. Read the value on Scale K, and record it in Table C-2, Unit Cost of Water.

FIGURE C - 4

LABOR COST NOMOGRAPH



1. Draw a straight line connecting the plant operating factor on Scale L with the nominal plant capacity on Scale M and note where an extension of this line crosses the pivot line, Scale N.

2. Draw a straight line connecting this point on the pivot line, Scale N, with the hourly labor cost on Scale P, and note where Scale Q--labor cost component--is crossed.

3. Read the labor cost component at this point and tabulate it in Table C-2, Unit Cost of Water.

KAISER ENGINEERS

TABLE C-4

EXAMPLES OF DESALINATION FACILITY CAPITAL COSTS AND UNIT COST OF WATER

	EXAMPLE 1			EXAMPLE 2			EXAMPLE 3			
Nominal plant capacity, gpd (see Note 1)		1,000,000			250,000				10,000,000	
Plant operating factor (see Note 1)		90%			95%				90%	
Economy ratio, lb product/lb steam (see Note 2)	8	10	12	6	8	10	8	10	12	14
Fixed charge rate (see Note 7)		8%			12%				7%	
Fuel cost, cents/million Btu (see Note 8)		25			35				30	
Hourly labor cost (see Note 9)		$14			$9				$20	
Conveyance, miles		4			2				6	
Plot size and land cost		3 acres @ $6,000 per acre			1 acre @ $2,000 per acre				10 acres @ $5,000 per acre	
Desalination Facility Capital Cost, dollars										
Desalination plant capital cost (see nomograph)	1,000,000	1,250,000	1,550,000	342,000	425,000	525,000	4,000,000	4,900,000	6,050,000	8,000,000
Heat source capital cost (see Note 3)	69,000	55,000	46,000	23,000	17,000	14,000	690,000	550,000	460,000	390,000
Product water conveyance capital cost (see Note 4)	108,000	108,000	108,000	44,000	44,000	44,000	430,000	430,000	430,000	430,000
Land capital cost (see Note 5)	18,000	18,000	18,000	2,000	2,000	2,000	50,000	50,000	50,000	50,000
Subtotal	1,195,000	1,431,000	1,722,000	411,000	488,000	585,000	5,170,000	5,930,000	6,990,000	8,870,000
Other capital costs and contingency (see Note 6)	239,000	286,000	344,000	82,000	98,000	117,000	1,030,000	1,190,000	1,400,000	1,770,000
Total Desalination Facility Capital Cost	1,434,000	1,717,000	2,066,000	493,000	586,000	702,000	6,200,000	7,120,000	8,390,000	10,640,000
Unit facility capital cost, $/daily gallon	1.43	1.72	2.07	1.97	2.34	2.81	.62	.71	.84	1.06
Unit Cost of Water, cents/1,000 gallons										
Fixed cost component (see nomograph)	35	41	51	68	83	99	14	15	18	23
Fuel cost component (see nomograph)	31	24	20	57	43	34	37	30	24	21
Labor cost component (see nomograph)	38	38	38	99	99	[illegible]	6	6	6	6
Chemicals and other unit costs (see Note 10)	8	8	8	8	8	8	8	8	8	8
Total Unit Cost of Water	112	111	117	232	233	240	65	59	56	58

TABLE C-5

TYPICAL COSTS OF ELECTRODIALYSIS PLANTS
(Based on Webster, S. D. Water)

Reference	(1)	(2)	(1)	(1)	(2)	(1)	(2)	(1)
Capacity, million gpd	0.25	.25	0.5	1.0	1.0	2	2.5	5
Annual production, million gal.	82.5	87.5	165	330	350	660	875	1.650
Number of stacks	1	-	2	4	-	8	-	20
Number Stages per stack	4	-	4	4	-	4	-	4
Number Membranes per stage	216 Pr	-	216 Pr	216 Pr	-	216 Pr	-	216 P
Capital Cost, $	$433,000	$401,000	$653,000	$1,065,000	$935,000	$1,865,000	$1,406,000	$4,065,000
$/daily gallon	1.73	1.60	1.31	1.07	.94	.93	.56	.81
	Annual Operating Costs - Dollars Per Year							
Direct Operating Costs								
1. Fuel	$ 400	$ 400	$ 500	$ 800	$ 800	$ 1,200	$ 1,200	$ 2,100
2. Electrical	6,400	4,200	12,200	23,900	14,800	47,000	26,700	116,300
3. Chemicals	7,100	6,200	14,300	28,600	34,000	57,100	150,000	142,800
4. Stores & Maint Mat'l	1,500	1,500	2,200	3,600	3,600	6,200	6,200	13,600
5. Membrane Replacement	17,600	11,600	32,000	58,400	43,800	106,300	35,100	235,100
6. Maintenance Labor	6,200	3,700	10,500	18,800	8,500	35,400	14,600	83,600
7. Operating Labor	2,900	7,600	3,000	5,900	20,200	17,800	31,100	17,800
Other Operating Costs								
8. Payroll Burden	1,400	1,400	2,000	3,700	4,600	8,000	8,600	15,200
9. G&A Overhead	3,200	3,200	4,700	8,500	6,500	18,400	13,700	35,000
10. Taxes & Insurance	8,400	8,100	12,600	20,400	20,400	35,600	33,500	77,800
11. Amortization	27,200	25,900	40,900	66,400	59,800	115,900	87,500	252,600
12. Interest on Work Capital	800	700	1,200	2,200	2,200	4,100	4,100	9,100
Total	$ 83,100	$ 74,500	$136,100	$ 241,200	$219,200	$ 453,000	$ 412,300	$1,001,000
¢/1,000 Gallons	101	85	83	73	63	69	59	60.6

Reference (1) - OSW Report No. 134 - An Engineering Evaluation of Electrodialysis Process Adapted for Computer Methods for Desalination Plants.

Reference (2) - OSW Report No. 164 - Third Annual Report Brackish Water Conversion Demonstration Plant, Webster, South Dakota

APPENDIX D

QUESTIONNAIRE

LISTING

DATA AND INFORMATION

FOR

PRELIMINARY FEASIBILITY STUDIES

AND

ENGINEERING FEASIBILITY AND ECONOMIC STUDIES

FOR

SINGLE-PURPOSE WATER DESALINATION

AND

DUAL-PURPOSE ELECTRIC POWER-WATER DESALINATION

PLANTS

INTRODUCTION

The questionnaire which follows is more extensive than will be required for any one preliminary feasibility study. Those data should be collected and questions answered only to the extent they would have a significant effect on the technical feasibility and economics of the proposed plant.

A. Climate

1. Provide for each site the following Normal, mean, and extreme Climatological Data:

   a. Average temperature

   b. Total precipitation

   c. Monthly and seasonal snowfall

   d. Monthly and seasonal degree days

   e. Average incident solar radiation (required only for solar distillation alternative) and average days per year of sunshine

   f. Relative humidity (%) maximum and minimum

   g. Narrative climatological summary

   Note

   Typical climatological data are included at the end of this section.

2. Provide wind rose data by seasons, including wind velocity, direction and percent duration at lapse and inversion conditions, ground level and normal stack height elevations.*

3. Provide atmospheric dispersion constants for lapse and inversion conditions.*

a. Mean wind velocity	$\bar{u}$	(meters/sec)
b. Stability parameter	n	
c. Diffusion constant	C_y	(meters $^{n/2}$)
	C_z	(meters $^{n/2}$)

*This information is required only when a nuclear reactor is being considered as a heat source.

4. Describe extreme climatic conditions which may influence design, construction, or operation of a plant at this site, including maximum recorded velocity and direction of wind, frequency and severity of sand storms, dust storms, tornadoes, typhoons, hurricanes, etc.

B. Geology Data

Provide the following general geology of area for each site to be considered:

Type of overburdens

a. Talus
b. Earth loose rock
c. Clay
d. Loam
e. Sand
f. Sandy gravel
g. Other

Average depth of overburden

Nature of underlying material

Ground Water (elevation)
Slides
Springs
Faults
Caves
Stratification of rock elevation
Air slacking
Describe area geologically

Soil bearing value:
Piles required: Length:
Available geological reports and related data:
Results of subsurface investigations:

C. Water Analysis

1. Water Chemistry

Provide complete data on water chemistry, including seasonal variations.

Total dissolved solids	____ppm	Suspended solids	____ppm
Sodium (Na^{+})	____ppm	Chloride (Cl^{-})	____ppm
Magnesium (Mg^{++})	____ppm	Sulfate (SO_4^{--})	____ppm
Calcium (Ca^{++})	____ppm	Bicarbonate (HCO_3^{-})	____ppm
Potassium (K^{+})	____ppm	Bromide (Br^{-})	____ppm
Iron* (Fe^{++}, Fe^{+++})	____ppm	Carbonate (CO_3^{--})	____ppm
Manganese* (Mn^{++++})	____ppm	Fluoride (F^{-})	____ppm
Silica (SiO_2)	____ppm	Other	____ppm
H_2S dissolved	____ppm		
O_2 dissolved	____ppm		
Total hardness	____ppm	Alkalinity	____ppm (as $CaCO_3$)
Chlorosity**	____gm/liter	Chlorinity**	____gm/kg
Salinity	____gm/kg	pH	____
Turbidity	____units (Jackson Candle Method)		

*Required only for membrane separation processes, electrodialysis and reverse osmosis

**Applicable only to dilute or concentrated seawater

2. Turbidity

   a. Provide any available qualitative or quantitative data on the turbidity of the water (over a period of time).

   b. To what is the turbidity due (e.g., plankton blooms, suspended sediment)?

   c. If the water contains suspended sediment, what is the approximate particle chemical composition?

3. Are organisms of the coliform group, fecal streptococci, or enteric viruses present in the raw water source?

4. Are anaerobic bacteria or pollution present in the raw water source, which might cause corrosion or affect the performance of process equipment?

D. Oceanography

1. Hydrography

   a. Provide monthly values of high, low and mean water temperature and variations with depth.

   b. Describe the extent of the thermocline at the site.

   c. Describe measurements and provide data (if available) on the dispersion from observation of dye patch drift or other tracking agents.

   d. Provide current data such as from a current meter installed and recording continuously near this area in about the same depth of water as the plant intake.

   e. Have the coastal currents been measured at the location on a regular basis, and what are their magnitudes and variations?

2. Waves

a. What is the maximum sea swell observed in the area at a depth of 12 to 15 meters?

b. Provide any wave refraction diagrams or other such work which has been done for the site.

c. Has the hindcast been prepared of the largest design wave in a period of 25 or 50 years?

d. What sea level datum is used for the site?

e. What is tide high, low and mean?

f. What is the largest inundation level ever noted?

g. Has this been due to a combination of high waves and tides?

h. What is the maximum expected height of storm tide at the location?

i. Provide any available hindcast of seasonal wave statistics, including the significant breaking height, period and breaker direction.

j. What is the nearest location for which tide gage measurements have been made over a long period of time? How long a period?

3. Littoral Processes

a. Have longshore currents been measured at the location, and if so, were they on a regular basis such as monthly or quarterly?

b. Provide any existing estimates of the anticipated littoral drift for the location.

c. Does the littoral drift vary seasonally, and how?

d. To what extend has erosion or accretion in the coastline at this location occurred historically in the last 10 years? In the last 50 years?

e. What has been the erosion or accretion on adjacent or down-coast areas?

4. Geology (Sedimentation and Structure)

   a. Provide any available recent detailed bathymetric chart of the area.

   b. Provide data on any representative bottom and beach samples which have been taken in connection with shoreline geological studies.

   c. What is the size distribution of beach and bottom sediments?

   d. Provide available profiles across the beach and berm, out to a depth of approximately 10 to 12 meters (seasonally).

   e. What is the thickness of unconsolidated sediment, and what is its thickness between the beach foreshore and berm out to a depth of 10 to 12 meters?

   f. What is the country formation underlying beach sands and marine sediments? Such as bed rock, hard clay or other.

5. Geology (Seismology)

   a. Are there any faults running through the plant site and are they active?

   b. What is the frequency of local earthquakes both onshore and offshore?

   c. What is the greatest earthquake magnitude which has been experienced locally?

   d. What is the expected height of tsunamis?

6. Biology

   a. To what extent are temperature and salinity fluctuations critical to marine flora and fauna in the area?

   b. What are the principal components in the algae at the location? At what depth is the region most productive? Is there historical documentation of fluctuation in the algae beds?

c. Is there a vertebrate fishery? If so, what are the species? Approximately how many tons are taken, at what times of the year?

d. Do local residents derive their food from the sea in this area? What are the principal products obtained? How many people obtain their food in this way? How often do they take food from the sea, and in what amounts?

e. What are the principal components of the benthos (from the sea bottom) fauna?

f. What are the problems of biological fouling in the area?

g. Are there migratory species of marine life including birds, large mammals such as whales, porpoises, etc, which frequent the area but are not harvested there?

h. Are there offshore kelp beds which may present intake problems?

7. Radiation*

a. Have any measurements been made of total beta or total gamma or other radioactivity in the offshore waters?

b. Have any background radiation studies been made of the flora and fauna of the area?

8. Miscellaneous

a. What amount of boat traffic, if any, exists in shallow water, i.e., boats of less than 15 meters?

b. What is the draft of these vessels?

c. Do they anchor and how are they powered, etc?

d. What is the extent of beach bathing or other water contact sports in the area?

e. Provide operating data on existing marine intake and outfall facilities.

f. Other existing or proposed uses of shore line or beaches in project area

*This information is required only when a nuclear reactor is being considered as a heat source.

E. Brackish Water Supply

1. Hydrology

a. What is the source of brackish water supply, i.e., wells, estuaries, river water, polluted or contaminated waste water, sewage treatment, plant effluent, etc?

b. Provide monthly values of high, low and mean water temperature and variation with depth.

c. If brackish water wells are raw water source, provide data on variations in water level with seasons and with pumping rate.

d. What is the sustained yield of wells as determined by the rate at which water moves through the aquifer.

e. Distance and height difference between point of saline surface supply and point of use.

f. Maximum lift if intermediate levels exist higher than site.

g. Number, type, average depth and capacity of existing wells and danger of seawater encroachment.

F. Engineering Design

1. Maps and Topography

a. Large scale topographic maps of project area

b. Vicinity maps (showing project area location with respect to major sites, existing transportation facilities, roads, railroad sidings, etc)

c. Property maps of project areas

d. Maps showing existing utilities in project areas

e. Horizontal and vertical control data

(1) Coordinate system(s)

(2) Bench marks

(3) Elevation datum

f. In the case of a coastal site, what is the elevation above sea level and distance from shore.

g. Size of plot _____ ft x _____ ft

h. Existing and/or proposed land use in project area

2. Codes, Standards and Specifications

a. Electrical construction, materials and equipment

b. Fire and fire protection

c. Concrete construction

d. Steel fabrication and erection

e. Building codes

f. Highway specifications

g. Railroad specifications and regulations

h. Harbor design regulations

i. Piping

j. Pressure vessels

k. Public health and waste disposal

l. Standards for irrigation and potable water

m. Nuclear safety

n. Industrial safety

3. Structures

a. Information on local design and construction practice for major structural materials including availability, facilities and limitations.

(1) Structural steel

(2) Fabricated steel

(3) Reinforced concrete

(4) Prestressed concrete

(5) Aluminum

(6) Concrete block

(7) Masonry block

(8) Timber

b. Material specification

(1) Cement

(2) Structural steel

(3) Rebar

(4) Concrete aggregate

c. Design Loads

(1) Live loads

(2) Wind loads

(3) Seismic loads

d. Allowable stresses

(1) Structural steel

(2) Reinforced concrete

(3) Prestressed concrete

e. Foundation Information

(1) Soil type, density and settlement

(2) Load bearing capacity at _____ ft below grade

(3) Soil properties including friction and cohesion

(4) Subgrade reaction

(5) Type of piles available for pile foundation

4. Drainage

a. Rainfall intensity duration curves

b. Design frequency, e.g., 5 yr, 10 yr, etc

c. Design procedure, e.g., Rational Method, etc

d. Standard practices and materials for drainage facilities including:

(1) Culverts

(2) Storm sewers

(3) Appurtenant structures

5. Highways

a. Pavement type

b. Pavement design procedure, e.g., CBR method, etc

c. Wheel loads

d. Typical pavement section and dimension

e. Operating criteria including:

(1) Grades

(2) Curves

f. Standards and criteria for appurtenant facilities and structure including bridges

6. Railroads

a. Gage

b. Rail weight

c. Curves and grades criteria

d. Turnouts

e. Typical road bed details and dimensions

f. Clearance and track spacing

g. Size and weight of rolling stock

h. Standards and criteria for appurtenant facilities and structures including bridges

7. Utilities

a. Availability at project area, conditions and cost, supply projects for 5, 20, 50 years.

(1) Water supply and quality

(2) Electric power - quantity, voltage, cycles, number of phases

(3) Steam - quantity, pressure, temperature, source, impurities

(4) Fuel oil grade and net heating value

(5) Gas - composition, net heating value (Btu/scf, Btu/lb)

(6) Solid fuels; coal, lignite, net heating value

(7) Communications

b. Availability and type of fuel oil for stand-by service

c. Construction standards and material specification

d. Is waste heat available from local industrial plants?

8. <u>Sewage Disposal</u>

a. Criteria for design capacity

b. Allowable methods of disposal at project areas

c. Design standards and criteria for sanitary services, sewage treatment and appurtenant facilities

d. Construction standards and material specification

9. <u>Brine Blowdown Disposal</u>

a. For a coastal site what are the design criteria for permissible temperature and salinity of brine blowdown and temperature of cooling water discharged into the ocean?

b. For an inland site are there rivers or streams into which brine blowdown and warm cooling water can be discharged without unacceptable effects on stream ecology? If so, what are the criteria for such effluents?

c. For an inland site are there underground strata into which brine effluent could be discharged without contaminating the brackish water source? If so, what is the depth?

d. For an inland site is impoundment and solar concentration of the brine blowdown possible?

10. <u>Waterworks and Product Water</u>

a. Required freshwater production

b. What is the intended use for the fresh water--domestic consumption, industrial, agricultural?

c. What product freshwater quality is required?

dissolved solids	_____ppm
hardness	_____ppm (as $CaCO_3$)
pressure	_____psig
pH	_____

d. Is chlorination, aeration, fluorination, passivation or other water treatment required?

e. Are taste additives required?

f. Can high-purity distilled water from a distillation plant be blended with a local mineralized source to increase the quantity of blended product water?

g. Does a dual water system (seawater and freshwater systems) exist and what is its capacity?

h. Hydraulic design standards and criteria

i. Controls and instrumentation standards and requirements for interconnecting service

j. Waterworks construction standards and material specification

k. Data on available pumping equipment

l. Corrosion problems and standards for corrosion protection

m. Availability of chlorine and sulphuric acid and standards for handling

n. Indicate the location and describe the connection point to water distribution grid

o. Describe the client-provided connection as to:

(1) Elevation above sea level

(2) Type, size, and description of pipe, conduit, or aqueduct

(3) System head-capacity curve at the connection point looking the direction of flow.

p. Describe any available or proposed freshwater storage facilities near enough to influence plant design

11. Electrical Connection

a. Indicate the location and describe the connection point to the electrical power distribution grid.

b. Describe the client provided connection as to:

(1) Proposed transformers or substation and switchyard

(2) Desired transformer or substation input voltage and frequency

(3) Power factor at maximum demand

(4) Number of proposed or desired feeders

(5) Preferred bus bar system (double breaker, or one and a half breaker for main and transfer bus)

(6) Circuit breaker interrupting requirements

c. Describe any special requirements with regard to generator characteristics which are necessary due to system considerations.

d. Provide a one-line diagram of the country or area system network with location of proposed sites indicated.

e. Describe the degree of automation desired, and the points of control in the plant and the system.

f. Describe any limitations to maximum unit size in this plant imposed by the system characteristics such as spinning reserve, possible transmission or power failures, etc.

g. Describe the seasonal power load variations on the power grid.

h. If a dual-purpose power generation-water desalination plant is being considered what will be the electrical load, plant load factor and unit power generation credit?

12. Chemical By-Products

Is there a local requirement for salt, magnesia, soda ash, bromine, caustic or chlorine which could be satisfied as a by-product from a desalination plant? If so what are the quantities required and at what prices might such by-products be marketed?

13. Operating Labor Rates

a. Superintendent ________ US $/mo
   Engineer ________ US $/mo
   Foreman ________ US $/hr
   Operator ________ US $/hr
   Maintenance ________ US $/hr
   Mechanic ________ US $/hr
   Clerk ________ US $/hr

b. What % allowance of the above rates must be made for fringe benefits such as vacation, holidays, sick leave, shift differential, insurance etc?

c. Normal working period ______ hr/day; ______ days/week; ______ holidays/year

14. Financial

a. Type of financing contemplated and interest rate

b. Currency exchange rate

c. Import duties imposed

d. Applicable local and/or federal taxes

15. Nuclear Hazards*

a. In the United States, the criteria for radiation protection for nuclear installations are contained in the U.S. AEC regulation 10 CFR 20, Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation." The criteria for reactor siting are contained in 10 CFR 100 "Reactor Site Criteria." Does the Government have similar regulations and, if not, what criteria are applied?

*This information is required only when a nuclear reactor is to be considered as a heat source.

b. Describe the population distribution in the vicinity of the proposed site(s). This should include sufficient detail to determine population in one-half mile, one-mile and 2-mile radii, and population and location of cities, towns and villages in a 20-mile radius.

c. Describe the population growth pattern including past and projected population of cities, towns and villages in a 20-mile radius.

d. Describe the source and occurrence of ground water on or adjacent to the site and its use or disposition after it leaves the site.

e. Location and depth of underground aquifers and porosity and ion-exchange capability of overlying soil.

f. Verify that wind rose data and atmospheric diffusion parameter data have been provided in response to questions in Subsection A, Climate.

G. Construction

1. Site Data

a. Identify and describe any physical features at the site, including existing construction, not shown on maps or drawings, that would have a bearing on the cost or difficulty of construction.

b. Blasting and other restrictions related to construction

c. Other proposed work at the site which may occur before or simultaneously with proposed construction

d. Easements required

e. Influence of other activities in project area, e.g., agriculture, industry, etc

2. Highways

Nearest town by highway: Distance Population
Routes traveled from town to jobsite:
Nearest large city: Distance Population
Routes traveled from city to site
Road mileage to other important points
Type and width of pavement
Maximum grades encountered on principal haul roads

Radius of sharpest curves
Height restrictions Describe

Bridges, weight limitations and conditions

Improvements required to meet plant needs

Alternate routes around any of the above limiting factors

Normal highway load restrictions
Maximum loads with permits
Wet or thawing weather load restrictions
"Off" highway equipment travel on public roads

Special conditions that would restrict highway transportation

(a) Weather
(b) Traffic
(c) Structures

General condition of maintenance and repair of roads

License fees or tax rates on hauling units

Gasoline, fuel oils, lube, and greases. Where obtainable

Cost

3. Railways

Name of nearest railway to work area

Main Line   Branch line   Single track   Double track

Name of nearest siding to work area

Length of siding   Owner

Number of switches to siding per day

Weight and size of maximum load railway can handle

Unloading docks at existing siding

Describe rolling stock of serving railroad

Operation (reliability, limitations on explosives, etc)

Rates

4. Rivers and Harbors

Name of nearest ocean port Distance

Maximum draft Max. crane capacity

Storage available

Rates and fees

Average clearing time

Restrictions (explosives, fuel, etc)

Bulk handling facilities (cement):

Owner

Obtain information from port authority as to facilities, rates, customs regulations, and tariffs

5. Labor

Must labor be recruited from other sources?
Where?
Travel allowance to and from job
Must overtime be paid or 6-days worked to secure labor?

Is labor unionized?

Does Government control rate of pay and conditions? (If yes, name agency, etc)

Is piece work common practice?
If yes, list rates

Is the use of a labor broker common practice?
List name, address, fees, etc:

Are bonuses or incentive wages paid?
If yes, list examples:

Basic work week
Hours after which overtime pay is paid
Basis for overtime pay
Paid holidays per year
Dismissal pay

Shift Premiums
Area Premiums
Subsistence or Camping Allowance
Vacation Pay
Maternity Benefits
Sick Benefits
Unemployment Benefits
Payroll Taxes
Compensation Insurance
Wet Pay
Dirty Pay
Height Premiums
Other

Direct Labor Rates

- Craft
  - Heavy Equip. Operator
  - Heavy Duty Mechanic
  - Truck Driver
  - Carpenter
  - Rebar
  - Rigger
  - Electrician
  - Welder
  - Pipefitter
  - Miner
  - Painter
  - Insulator
  - Boilermaker
  - Concrete Laborer
  - Common Laborer

Indirect Labor Rates

Supervision

Superintendents
Walkers Foremen

Office Help

Office Manager
Chief Accountant
Assistant Accountant
Head Timekeeper
Timekeepers
Clerks
Secretaries
Stenographers

Industrial Relations

Industrial Relations Manager
Safety Engineer
Claims Officer
Doctor
Male Nurse
Female Nurse

Purchasing

Purchasing Agent
Buyer
Warehouse Foreman
Warehousemen

Engineering

Office Engineer
Design Engineer
Draftsmen
Jr. Engineer
Field Engineer
Instrumentmen
Chairman

Describe briefly local labor productivity in terms of U.S. labor. How large are gangs? Do religious or other local customs affect working conditions?

6. <u>Housing</u>

Location and type of camp and housing site.

Food supply.

Water supply
Sewage disposal
Hospitals
Schools
Doctors
Recreational facilities
Churches
Fire protection
Police protection
Transportation to nearest towns

Cost of renting housing and offices in town
Source of information:

<u>Local Cost</u>

Cost constructing houses for U.S. personnel per sq ft
Cost constructing barracks for U.S. personnel per sq ft
Cost constructing houses for other personnel per sq ft
Cost constructing barracks for other personnel per sq ft
Sq ft of barracks required per man
Cost of providing meals per each
U.S. Hire
Other:

<u>Miscellaneous</u>

Pest Control
Public Health
Prevalent Diseases
Methods and costs of combating diseases

7. <u>Materials</u>

Provide information on the source, availability, specifications or quality, dependability of supply and delivery, and cost of the following basic construction materials.

Explosives
Reinforcing steel
Steel shapes
Steel plate
Sheet metal
Steel pipe (by size and schedule)
Pipe fittings (by size and schedule)
Electrical wire
Electrical fixtures
Electrical motors
Electrical supplies
Fabricated steel
Lumber
Plywood
Aluminum
Concrete pipe (by size, type and rating)
Asbestos cement pipe (by size and rating)
Asphalt products (paving)
Petroleum products
Other applicable materials (wire, concrete products, nails, bolts, hose, paint, welding rod, electrical conduit and fittings)

Source and type of aggregates and treatment required

Source and type of cement

Cost and availability of cement (shipped in bags or bulk)

Location of quarries or borrow pits, and haul distances (for sand, gravel, rock)

Location of Waste Area

8. Construction Equipment

Types, approximate amounts available, capacity and monthly rental costs of construction equipment.

Trucks
Automobiles
Welding machines; gasoline engine driven, electric driven
Lowboy trailers
Concrete mixers
Pile drivers
Earth moving equipment
Cranes
Portable electric plants
Pumps
Scaffolding
Hoists and tuggers
Air compressors

9. Contractors

Availability of local contractors and subcontractors

10. Fabricators

Availability of local fabricators

Structural steel
Vessels and tanks
Piping
Electrical equipment
Other

11. Estimating Data

Available data on unit construction costs for estimating purposes

12. Taxes and Fees

Income taxes

Locals
Expatriates
Business taxes (Can company be taxed for income not earned in country?)

Tax Rates and Laws

Business licenses and fees
Stamp taxes
Others

Customs Duties

Construction Equipment from Dollar area
Construction Equipment from Sterling area
Construction Equipment from other area

Permanent Materials from Dollar area
Permanent Material f m Sterling area
Permanent Materials from other area

Materials and Supplies from Dollar area
Materials and Supplies from Sterling area
Materials and Supplies from other area

Miscellaneous Taxes, Etc

Restriction on insurance, compensation, transportation, etc

Public Liability Insurance, Rates per $100 Payroll

Contract Bond Premium	% of Contract Amount
Special Surety Bond	Rate

13. Check List for Documents

The following books and documents should be obtained in English:

Handbook of Commerce and Industry
Labor Laws
Insurance Laws Including Social Insurance
Alien Registration Laws
Railroad Facilities and Rates
Port Facilities and Rates
Highway Limitations and Rates
Customs Duties and Import and Export Restrictions
Business Registration Laws
Tax Laws Both Personal and Business
Safety Laws or Codes
Explosive and Flammable Liquid Codes
Compulsory Savings Laws
Exchange Control Restrictions

H. Photographs

1. Photographs of project area with identification.

2. Aerial photographs of project area. Stereo pairs if available.

I. Remarks and Miscellaneous

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU

LOCAL CLIMATOLOGICAL DATA

WITH COMPARATIVE DATA

1953

TEXARKANA, ARKANSAS

NARRATIVE CLIMATOLOGICAL SUMMARY

Texarkana is located in northeast Texas and southwest Arkansas astride the Texas-Arkansas state line, with the Weather Bureau station at the Municipal Airport on the Arkansas side of the state line. In this location it is more or less protected by the Ozark Mountains from the more severe winds and cold waves that come down out of Canada. Thus the normal winters in this area are relatively mild. Records covering the last 42 years show mean temperatures of 47.6°, 46.0° and 49.1° for December, January and February, respectively. In only two years, 1930 and 1951, has the temperature been below zero, and then for only one day at a time and to extreme lows of -3°F. An average of lowest-for-the-month January temperature readings is 16.9°, while the mean minimum temperature for that month is 35.6°. In 19 of the 42 years of record the lowest January temperature was 20° or higher, and in 7 of these years it did not go below 25°.

The spring and autumn months are mild with cool nights and warm days. Average temperature for the spring months is 64.0° and for the autumn months 66.3°. Summers are usually rather mild but the high humidity of this area, where the warm moist winds from the gulf meet the cooler air from the land areas, causes high temperatures to be more oppressive than they would be in dryer air. An average of the highest-for-the-month July temperature readings is 102.2°, while the average maximum temperature for that month is 94.5°. The highest temperature ever recorded for this station is the 117° that occurred on August 10, 1936. The lowest maxima for June, July and August are 93°, 93° and 94°, respectively. Summer nights in this area are frequently uncomfortable, partly because of the high humidity but primarily because the wind becomes calm or almost so in the late afternoon and frequently remains so all night.

Mean annual rainfall for the last ten years is 50.24 inches, while for the 41 year period ending with the same decade, it is 49.72 inches. This difference is explained largely by the fact that three of the last ten years were unusually wet, with sixty or more inches each. The greatest monthly rainfall occurred in October 1919 when 18.28 inches was recorded. The greatest for any 24-hour period was the 9.29 inches that fell in October 1926. The wettest year for Texarkana since 1911 was 1937 with a total fall of 67.97 inches, while the dryest year for the same period was 1924 when the total was only 31.00 inches.

Snowfall in Texarkana is usually very light with only an occasional fairly heavy fall. The heaviest 24-hour snowfall recorded was 4.5 inches in January 1949.

Thunderstorms are frequent from May until September but no severe hailstorms have been recorded during the period of record. On the other hand, several small tornadoes have occurred.

LATITUDE 33° 27' N
LONGITUDE 94° 00' W
ELEVATION (ground) 361 FEET

METEOROLOGICAL DATA FOR THE CURRENT YEAR

TEXARKANA, ARKANSAS
MUNICIPAL AIRPORT
1953

Month	Temperature: Averages: Daily maximum	Daily minimum	Monthly	Extremes: Highest	Date	Lowest	Date	Degree days	Precipitation: Total	Greatest in 24 hrs.	Date	Snow, Sleet, Hail: Total	Greatest in 24 hrs.	Date	Relative humidity: 12:30 A.M. CST	6:30 A.M. CST	12:30 P.M. CST	6:30 P.M. CST	Wind: Average hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Date	Percent of possible sunshine	Average sky cover sunrise to sunset	Number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet, Hail 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Maximum: 90° and above	32° and below	Minimum: 32° and below	Zero and below
JAN	60.2	38.3	49.3	75	26	28	17	480	5.47	2.34	30-31	T	T	23	76	84	64	69	11.6	S	40	SSW	26	-	5.6	11	7	13	8	0	3	2	0	1	8	0
FEB	60.6	37.9	49.3	78	27	25	22	435	1.83	0.68	18-19	0.0	0.0		78	84	58	63	8.7	WNW	35	W	20	-	5.8	9	7	12	9	0	3	1	0	0	7	0
MAR	71.5	50.3	60.9	83	31	34	5	164	5.35	1.84	9-10	T	T	22	74	83	59	58	8.8	SSE	36	W	3	-	6.7	6	8	17	15	0	6	6	0	0	0	0
APRIL	73.0	49.7	61.4	84	9+	33	19	137	7.61	2.90	23-24	T	T	24	76	82	56	58	9.8	S	65	W	24	-	4.8	11	10	9	10	0	7	3	0	0	0	0
MAY	82.2	62.4	72.3	95	29	46	5	30	8.12	1.99	16	T	T	19	86	90	65	69	8.5	S	47	SW	12	-	5.8	8	14	9	11	0	9	1	10	0	0	0
JUNE	95.9	73.3	84.6	102	21	68	1	0	0.30	0.16	28	0.0	0.0		76	83	48	48	7.0	S	37	NE	11	-	2.7	23	4	3	3	0	2	0	28	0	0	0
JULY	90.9	71.7	81.3	100	6	64	11	0	7.69	3.14	17	0.0	0.0		85	92	64	65	5.7	NE	22	NW	21	-	5.7	9	11	11	10	0	11	2	21	0	0	0
AUG	91.4	70.2	80.8	98	15+	64	21+	0	2.90	1.95	18-19	0.0	0.0		84	90	58	66	5.4	NE	35	S	18	-	4.8	12	12	7	6	0	10	0	21	0	0	0
SEPT	91.0	62.2	76.6	102	28	49	23	0	0.64	0.62	3-4	0.0	0.0		-	86	43	51	-	-	-	-	-	-	1.9	23	4	3	3	0	1	0	19	0	0	0
OCT	81.4	54.6	68.0	95	1	39	30	74	0.78	0.69	25-26	0.0	0.0		-	80	45	51	-	-	-	-	-	-	4.4	14	6	11	3	0	2	0	5	0	0	0
NOV	64.9	40.1	52.5	77	19+	29	10	370	2.54	1.14	3-[illegible]	0.0	0.0		-	85	48	60	-	-	-	-	-	-	4.0	17	4	9	8	0	2	0	0	0	4	0
DEC	54.5	34.1	44.3	68	5	16	24	635	3.81	1.83	2-3	0.0	0.0		-	79	56	63	-	-	-	-	-	-	5.2	14	4	13	10	0	1	2	0	0	14	0
Year	76.5	53.7	65.1	102	SEPT 28+	16	DEC 24	2325	47.04	3.14	JULY 17	T	T	MAY 19+	-	85	55	60	-	-	-	-	-	-	4.8	157	91	117	96	0	57	17	104	1	33	0

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Sleet, Hail: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: 12:30 A.M. CST	6:30 A.M. CST	12:30 P.M. CST	6:30 P.M. CST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet, Hail 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max: 90° and above	32° and below	Min: 32° and below	0° and below
(a)	(b)	(b)	(b)	11		11		(b)	(b)	11		11		11		11	11		11			11	11	11							9	11	11	11	11	11	11	11	11	11	11	11
J	56.3	35.5	45.9	83	1950+	6	1943	600	5.12	9.55	1949	1.64	1943	4.04	1949	1.7	6.1	1946	4.5	1949	-	86	67	71	-	-	-	-		-	7.1	8	6	17	11	1	2	3	0	2	12	0
F	60.4	38.6	49.5	84	1950	- 3	1951	441	4.10	9.44	1950	1.01	1947	3.85	1950	0.2	1.8	1948	1.8	1948	-	84	62	64	-	-	-	-		-	5.3	8	6	14	11	*	4	3	0	*	7	*
M	67.7	44.3	56.0	90	1946	11	1943	324	4.93	15.33	1945	3.63	1947	5.36	1945	T	T	1953+	T	1953+	-	81	57	57	-	-	-	-		-	5.3	8	8	15	12	0	6	2	*	0	3	0
A	76.7	53.3	65.0	91	1943	33	1953	84	5.30	8.00	1944	2.40	1949	3.00	1952	T	T	1953+	T	1953+	-	84	55	55	-	-	-	-		-	5.9	9	9	12	10	0	7	1	*	0	0	0
M	83.1	60.6	71.9	95	1953+	42	1944	0	5.13	12.05	1946	1.93	1949	3.77	1947	T	T	1953+	T	1953+	-	88	59	61	-	-	-	-		-	5.9	9	10	12	10	0	10	1	3	0	0	0
J	91.0	68.7	79.9	102	1953	53	1947	0	3.85	10.31	1945	0.30	1953	6.55	1945	T	T	1952	T	1952	-	88	57	58	-	-	-	-		-	5.0	10	12	8	7	0	8	*	20	0	0	0
J	94.6	71.1	82.9	105	1944	59	1947	0	3.94	7.69	1953	0.39	1947	3.14	1953	0.0	0.0		0.0		-	89	56	58	-	-	-	-		-	5.7	9	13	9	8	0	9	1	23	0	0	0
A	94.5	70.9	82.7	106	1947	57	1949	0	2.88	8.49	[illegible]	0.20	1943	2.93	1944	0.0	0.0		0.0		-	88	53	56	-	-	-	-		-	4.7	11	13	7	6	0	8	*	23	0	0	0
S	89.7	64.7	77.2	105	1951	43	1949	0	2.79	7.26	[illegible]	0.04	1952	2.13	1950	0.0	0.0		0.0		-	88	53	59	-	-	-	-		-	4.5	14	8	8	6	0	5	*	12	0	0	0
O	80.2	53.7	67.0	95	1953	30	1942	69	3.38	[illegible]	[illegible]	0.33	1952	2.92	1949	0.0	0.0		0.0		-	87	50	60	-	-	-	-		-	4.2	16	7	8	5	0	3	2	1	0	*	0
N	66.7	42.9	54.8	84	1951+	21	1951+	317	4.33	9.91	[illegible]	0.22	1949	4.09	1944	T	T	1952+	T	1952+	-	84	56	64	-	-	-	-		-	5.2	12	7	11	8	0	3	2	0	0	5	0
D	58.4	37.5	48.0	82	1951	13	1950	527	4.84	9.45	1944	0.19	1950	3.02	1944	T	T	1952+	T	1952+	-	82	59	66	-	-	-	-		-	6.8	10	6	15	9	0	2	2	0	1	12	0
Year	76.6	53.5	65.1	106	AUG 1947	- 3	FEB 1951	2362	50.59	15.33	MAR 1945	0.04	SEPT 1952	6.55	JUNE 1945	1.9	6.1	JAN 1946	4.5	JAN 1949	-	86	57	61	-	-	-	-		-	5.6	124	105	136	103	1	67	17	82	3	39	*

(a) Length of record, years. (b) Normal values are based on the period 1921-1950, and are means adjusted to represent observations taken at the present standard location.

See Reference Notes on last page.

AVERAGE TEMPERATURE

Year	Jan	Feb	Mar	Apr	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	An'l
1911							80.6	81.6	82.1	67.1	52.1	47.3	
1912	41.5	45.3	47.9	63.2	71.2	76.5	83.5	80.3	77.9	67.2	53.4	43.3	62.8
1913	47.3	43.7	50.8	62.7	71.9	79.0	83.6	84.8	73.8	64.6	62.8	48.2	64.3
1914	49.2	41.3	52.5	62.6	70.5	82.6	85.6	80.7	77.4	65.3	54.9	40.0	63.8
1915	42.4	48.9	45.1	65.1	72.1	79.8	80.5	77.3	78.9	66.1	58.7	50.6	63.6
1916	49.8	46.0	56.4	62.2	72.7	78.2	84.1	84.3	76.7	66.1	55.8	48.6	65.1
1917	49.8	51.4	57.0	63.0	66.6	78.4	82.8	80.5	75.7	59.8	54.1	42.9	63.5
1918	35.3	50.1	60.6	63.0	73.2	83.5	82.7	84.9	72.9	69.6	53.3	50.8	65.0
1919	44.8	49.8	57.6	65.2	69.5	78.2	83.6	82.4	76.4	70.0	56.1	46.3	65.0
1920	44.9	51.6	57.0	63.3	74.3	78.3	82.5	79.5	78.8	66.4	51.8	49.1	64.8
1921	53.3	55.0	66.5	63.5	74.5	80.8	83.9	84.6	82.5	66.5	61.2	53.4	68.8
1922	44.7	53.8	56.2	67.0	76.7	81.1	82.6	82.8	79.1	67.1	57.6	55.1	67.0
1923	54.8	49.2	54.3	65.6	71.1	79.2	83.1	84.7	75.1	64.0	54.1	54.1	65.8
1924	42.0	47.0	52.1	64.7	67.6	81.9	82.8	87.4	75.3	70.2	57.6	46.8	64.6
1925	43.4	53.3	57.3	68.1	70.3	83.6	84.6	82.9	82.1	63.3	53.5	43.5	65.5
1926	45.3	53.6	51.9	61.0	71.3	77.1	80.2	82.3	79.9	68.4	51.5	48.6	64.3
1927	47.3	56.1	57.4	69.2	74.5	79.2	82.2	82.0	78.7	69.6	60.5	44.5	66.8
1928	46.9	49.3	58.5	61.7	73.4	77.7	83.3	85.4	78.7	69.0	53.7	48.1	65.3
1929	45.1	40.8	60.2	67.6	71.7	79.6	82.7	82.9	73.0	64.4	48.4	46.6	63.7
1930	37.9	54.5	52.5	68.2	70.3	78.4	85.6	83.2	76.5	61.7	53.0	42.9	63.7
1931	45.4	50.3	48.9	60.2	67.0	79.7	83.4	78.8	70.7	70.4	60.0	50.5	64.5
1932	48.4	55.1	52.4	65.8	71.2	81.2	83.6	83.6	76.4	64.1	50.1	45.2	64.8
1933	53.4	45.4	56.4	63.8	73.6	79.0	82.2	80.8	80.0	64.4	56.2	53.5	65.7
1934	47.2	46.5	52.8	65.3	71.0	80.8	85.2	87.6	75.6	70.3	57.4	45.8	65.4
1935	47.2	48.8	61.2	63.5	68.8	76.6	82.6	84.2	73.8	66.1	52.7	41.7	63.9
1936	41.1	40.8	60.6	62.6	73.2	82.8	84.0	88.6	82.9	63.8	52.0	50.0	65.2
1937	45.7	49.8	52.4	64.5	73.4	80.6	81.4	84.0	77.4	64.6	52.6	47.9	64.5
1938	48.0	55.4	64.7	64.6	73.4	78.9	83.9	85.7	79.0	71.3	55.1	48.8	67.4
1939	50.3	49.3	59.0	64.0	74.4	82.9	86.5	85.6	84.3	69.5	53.7	51.9	67.6
1940	36.0	48.0	57.2	64.9	69.8	77.2	80.3	79.5	75.2	69.8	54.0	51.8	63.6
1941	49.6	46.2	52.2	66.4	74.0	77.8	81.6	82.8	77.8	71.2	53.0	48.8	65.1
1942	43.2	46.0	56.4	69.4	71.6	80.3	83.2	81.5	73.4	65.6	58.5	46.8	64.7
1943	44.9	51.1	50.5	67.1	74.2	82.2	83.3	85.8	74.8	65.0	53.5	44.6	64.7
1944	45.8	51.8	55.0	63.8	71.6	81.8	84.0	82.8	76.0	66.8	56.0	42.6	64.8
1945	43.8	48.5	61.4	64.8	69.4	78.4	80.2	80.6	77.2	63.7	57.7	42.1	64.0
1946	43.8	51.1	60.0	68.0	69.3	77.6	81.9	80.9	74.5	66.4	56.0	52.1	65.1
1947	45.8	41.0	48.8	65.0	70.0	79.0	81.2	85.1	77.0	70.9	51.0	48.2	63.6
1948	37.3	46.4	54.4	68.6	72.0	80.6	83.4	81.8	75.9	64.3	53.6	49.6	64.0
1949	45.9	50.4	55.5	63.1	75.0	80.2	82.8	79.9	73.2	65.7	57.1	50.0	64.9
1950	53.2	51.8	53.6	61.8	72.9	78.2	78.8	78.8	72.1	68.9	52.2	43.2	63.8
1951	45.3	48.4	55.3	61.7	71.6	78.6	83.3	86.0	75.9	66.4	49.9	48.8	64.3
1952	52.7	52.3	53.4	60.6	71.1	82.5	83.4	83.3	75.8	60.1	52.5	45.6	64.5
1953	49.3	49.3	60.9	61.4	72.3	84.6	81.3	80.8	76.6	68.0	52.5	44.3	65.1
MEAN TEMP	46.2	49.3	55.4	64.2	71.8	80.3	82.1	82.4	75.3	66.0	53.9	46.5	64.4
MAX	55.3	59.3	65.8	74.8	81.9	90.2	92.4	93.1	86.4	78.1	64.7	56.1	74.8
MIN	37.0	39.2	44.9	53.5	61.6	70.4	72.8	71.7	64.2	53.9	43.0	36.8	54.0

TOTAL PRECIPITATION

Year	Jan.	Feb	Mar.	Apr.	May	June	July	Aug	Sept	Oct	Nov.	Dec	Annual
1911							5.62	3.51	0.62	1.35	2.57	6.66	-
1912	2.33	1.32	9.19	6.30	3.89	3.90	2.25	4.91	0.70	1.18	0.58	4.33	40.88
1913	5.92	5.30	4.94	2.33	3.81	1.18	2.71	1.87	9.61	2.49	1.02	3.96	45.14
1914	1.37	4.13	4.94	8.00	4.92	0.10	0.94	6.31	0.70	0.32	2.52	6.18	40.43
1915	4.54	3.45	3.70	5.17	2.55	3.58	2.85	12.87	1.80	1.55	6.64	3.56	52.26
1916	7.82	0.33	1.27	3.47	3.05	5.34	1.39	5.70	0.39	2.19	2.60	2.02	35.57
1917	3.40	3.25	4.02	6.53	1.25	5.65	8.80	3.17	1.12	0.94	3.30	1.65	43.08
1918	0.90	1.25	4.11	6.52	0.77	3.00	0.75	3.21	2.70	3.10	5.50	5.13	36.94
1919	2.40	4.14	4.95	3.20	3.30	3.73	3.00	7.71	2.93	18.28	7.55	1.82	63.01
1920	8.39	1.47	4.71	6.35	9.47	3.23	7.20	4.80	2.45	8.58	1.75	6.68	64.88
1921	3.30	1.57	5.91	10.37	2.81	4.65	5.25	1.76	4.16	0.94	4.02	3.79	48.53
1922	3.25	5.45	7.52	10.34	4.03	4.39	4.44	4.74	0.98	1.35	0.71	1.68	48.88
1923	9.64	5.08	4.23	5.15	4.23	6.18	2.89	2.28	7.27	4.00	2.25	7.17	60.55
1924	3.18	2.22	3.83	5.08	4.63	2.35	0.65	0.99	2.41	0.25	2.64	2.77	31.00
1925	3.23	3.37	1.87	3.81	3.77	1.58	5.09	1.88	4.15	7.47	6.22	1.50	43.94
1926	4.71	1.75	0.93	5.81	4.98	2.87	6.49	4.75	1.73	12.08	2.13	8.67	62.88
1927	3.28	5.96	4.56	8.28	4.61	5.31	1.03	2.78	5.33	1.15	2.15	3.79	51.21
1928	1.38	4.94	1.82	5.72	4.41	7.73	4.54	2.23	0.15	5.88	5.70	7.27	51.75
1929	5.61	3.76	4.08	3.67	8.23	0.85	3.60	0.30	2.33	1.86	3.02	3.56	40.97
1930	11.02	4.59	3.91	1.87	15.35	0.15	0.15	3.93	3.65	6.78	8.70	3.65	61.75
1931	1.81	4.00	4.73	2.40	1.94	3.68	8.04	3.55	0.90	2.14	7.72	7.65	48.56
1932	10.00	6.13	6.41	2.73	0.84	3.92	3.23	1.12	0.87	2.30	1.42	8.72	50.69
1933	4.03	2.99	3.45	4.43	3.03	0.72	7.70	2.08	3.30	5.17	1.22	6.91	46.56
1934	1.03	2.59	5.98	5.42	2.86	4.22	2.25	0.22	1.35	0.35	7.58	4.89	41.34
1935	8.12	3.65	3.88	5.16	6.59	5.71	1.05	0.83	3.23	4.56	5.52	3.65	51.59
1936	1.87	1.28	1.71	1.59	4.51	T	2.68	1.31	2.75	3.83	1.66	5.18	28.39
1937	14.97	3.69	4.70	3.99	3.42	5.66	3.21	5.94	0.32	3.92	9.19	[illegible]	[illegible]
1938	9.80	3.98	4.74	5.08	2.65	6.92	2.70	1.51	3.14	1.84	4.83	[illegible]	[illegible]
1939	6.18	8.49	3.85	3.97	1.16	3.27	0.99	1.03	0.99	1.43	7.79	3.08	42.25
1940	1.38	2.92	2.70	10.35	6.41	6.17	15.19	4.33	0.25	1.90	9.40	4.43	65.43
1941	2.62	3.73	6.34	9.26	3.87	4.62	6.49	5.20	4.08	4.34	2.77	6.2[illegible]	59.54
1942	2.35	1.39	4.78	9.90	3.72	5.84	0.70	7.66	3.75	2.13	0.64	4.71	47.57
1943	1.84	1.18	3.87	3.11	6.77	2.54	2.25	0.20	2.35	3.58	0.62	3.35	31.66
1944	4.14	8.19	6.27	8.00	6.89	2.73	0.67	8.49	1.86	1.10	8.66	3.45	68.45
1945	2.29	6.61	15.33	4.04	3.49	10.31	4.05	1.63	5.08	1.93	3.64	3.29	61.69
1946	8.17	4.97	5.49	5.90	12.05	3.31	2.98	2.85	0.89	2.54	9.91	1.91	61.00
1947	2.45	1.01	3.63	2.97	6.80	3.11	0.39	3.11	3.08	2.50	6.88	7.17	43.19
1948	3.21	5.12	5.67	3.99	6.95	1.50	3.71	2.93	0.23	2.46	4.07	3.07	42.91
1949	9.55	2.85	4.23	2.40	1.93	3.42	5.31	1.59	3.96	9.78	0.22	3.84	49.08
1950	7.85	9.44	5.82	4.15	11.42	2.25	5.25	4.90	7.28	1.74	0.48	0.19	60.75
1951	4.47	4.25	2.54	5.56	2.98	5.95	3.65	1.18	5.32	3.48	2.03	2.38	43.79
1952	2.28	2.15	6.13	6.55	3.92	2.23	2.35	2.50	0.04	0.33	9.22	4.10	41.80
1953	5.47	1.83	5.35	7.61	8.12	0.30	7.69	2.90	0.64	0.78	2.54	3.81	47.04
MEAN	4.68	4.33	5.85	4.93	6.48	3.13	3.48	2.93	2.79	2.75	4.39	3.99	49.93

MONTHLY AND SEASONAL SNOWFALL

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr.	May	June	Total
1942-1943	-	-	-	-	-	-	T						-
1943-1944							1.9						1.9
1944-1945						T							T
1945-1946						T	6.1	T					6.1
1946-1947						T	T	T	T				T
1947-1948							2.2	1.8	T				4.0
1948-1949							4.5		T				4.5
1949-1950							T	T	T				T
1950-1951					T	T	4.3		T	T	T		4.3
1951-1952					T			T	T	T		T	T
1952-1953					T	T	T		T	T	T		T
1953													

MONTHLY AND SEASONAL DEGREE DAYS

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
1911-1912	0	0	0	103	403	548	730	570	535	112	28	0	3026
1912-1913	0	0	8	65	349	673	554	596	462	144	10	0	2861
1913-1914	0	0	38	158	129	582	495	664	408	129	16	0	2619
1914-1915	0	0	4	121	316	774	702	452	618	94	11	0	3092
1915-1916	0	0	2	59	245	460	178	552	299	134	27	0	2256
1916-1917	0	0	19	91	308	520	484	403	310	128	85	0	2326
1917-1918	0	0	0	232	328	693	921	427	177	124	22	0	2924
1918-1919	0	0	15	11	371	451	627	425	239	84	18	1	2272
1919-1920	0	0	0	28	271	579	636	394	269	129	10	0	2306
1920-1921	0	0	4	74	116	499	375	286	81	97	19	0	1851
1921-1922	0	0	0	57	159	367	631	350	284	52	0	0	1900
1922-1923	0	0	0	65	248	359	325	453	335	64	11	0	1858
1923-1924	0	0	0	137	326	358	714	521	410	94	43	0	2603
1924-1925	0	0	6	40	254	596	670	331	261	39	31	0	2231
1925-1926	0	0	0	194	349	667	612	321	409	150	15	7	2724
1926-1927	0	0	2	56	410	508	550	257	276	41	3	0	2103
1927-1928	0	0	1	15	180	813	589	158	245	151	1	0	2261
1928-1929	0	0	0	55	347	523	618	657	216	38	13	0	2467
1929-1930	0	0	0	95	503	577	841	303	389	16	9	0	2733
1930-1931	0	0	4	164	367	884	801	414	501	167	56	0	2959
1931-1932	0	0	0	58	191	151	518	291	422	51	0	0	1985
1932-1933	0	0	0	99	452	598	357	561	282	91	0	0	2116
1933-1934	0	0	0	71	280	367	551	524	300	59	0	0	2251
1934-1935	0	0	0	18	250	593	555	460	177	107	37	0	2197
1935-1936	0	0	6	61	384	721	744	715	119	163	0	0	2913
1936-1937	0	0	6	110	406	468	598	437	393	106	14	0	2519
1937-1938	0	0	4	91	386	527	522	277	94	115	10	0	2026
1938-1939	0	0	2	35	332	511	454	440	203	108	0	0	2085
1939-1940	0	0	1	72	346	404	895	499	256	108		0	2585
1940-1941	0	0	10	19	331	409	181	517	404	45	0	0	2216
1941-1942	0	0	0	57	319	195	618	463	182	36	0	0	2209
1942-1943	0	0	41	63	242	577	629	390	457	63		0	2167
1943-1944	0	0	0	94	359	641	586	388	320	96	32	0	2316
1944-1945	0	0	0	55	296	695	661	466	169	87	45	0	2474
1945-1946	0	0	0	103	267	708	659	389	175	11	11	0	2353
1946-1947	0	0	3	67	290	407	595	675	503	70	8	0	2618
1947-1948	0	0	5	12	419	521	860	542	367	42	1	0	2773
1948-1949	0	0	2	88	354	194	599	407	296	128	0	0	2368
1949-1950	0	0	10	102	258	471	389	373	365	149	3	1	2127
1950-1951	0	0	7	16	404	676	603	463	306	155	7	0	2637
1951-1952	0	0	0	73	455	511	397	362	367	155	11	0	2333
1952-1953	0	0	0	201	396	505	180	435	164	137	30	0	2438
1953	0	0	0	74	370	635							

See Reference Notes on last page.

REFERENCE NOTES

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation and snowfall in inches; wind movement in miles per hour; and relative humidity in percent.

Sky cover is expressed in a range of 0 for no clouds or obscurations to 10 for complete sky cover. Degree days are based on daily average temperatures of 65°F. Sleet and hail were included in snowfall totals beginning with July 1948.

Heavy fog in the Means and Extremes Table also includes data referred to at various times in the past as "Dense" or "Thick". The upper visibility limit for heavy fog is 1/4 mile.

Below-zero temperatures are preceded by a minus sign.

The horizontal lines drawn on the Average Temperature, Total Precipitation, Monthly and Seasonal Degree Days, and Monthly and Seasonal Snowfall tables separate the data according to station location (see Station Location table).

- * Less than one-half.
- \- No record.
- \+ Also on earlier dates, months, or years.
- T Trace, an amount too small to measure.

Mean values at the end of the Average Temperature and Total Precipitation tables are averages based on the period of record beginning in 1943. Values have not been corrected for changes in instrument location listed in the Station Location table.

Data entered in column headed Fastest Mile is the fastest mile observed. This station is not equipped with automatic recording wind instrument.

Data from cooperative station prior to August 1942.

STATION LOCATION

Location	Occupied from	Occupied to	Airline distance and direction from previous location	Latitude	Longitude	Elevation above											Remarks
						Sea level		Ground									
						Ground	Actual barometer elevation (H_p)	Wind instruments	Extreme thermometers	Psychrometer	Telepsychrometer	Tipping bucket rain gage	Weighing rain gage	8" rain gage			
Exact location unknown	4/-/83	6/30/11		33° 24'	94° 02'	320											
1217 Hazel Street	7/1/11	3/31/35		33° 24'	94° 02'	320											
2824 Magnolia	4/1/35	8/30/42	3/4 mi N	33° 25'	94° 02'	332											
Municipal Airport, Admin. Bldg., 3 1/4 mi NE of Post Office	9/1/42		3 mi ENE	33° 27'	94° 00'	361	368	32	7	7			5	4			CAA station operative 4-1-31 until 4-24-42

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W.R.P.C., Kansas City, Mo. -- 3-30-54 -- 215