

The Salt Storage Handbook



Salt Institute

The Salt Storage Handbook



A Practical Guide for Storing and Handling Deicing Salt

Published by



Copyright © by the **Salt Institute** 1968, 1980, 1986, 1987, 1997, 2006
700 North Fairfax Street, Suite 600, Alexandria, VA 22314-2040

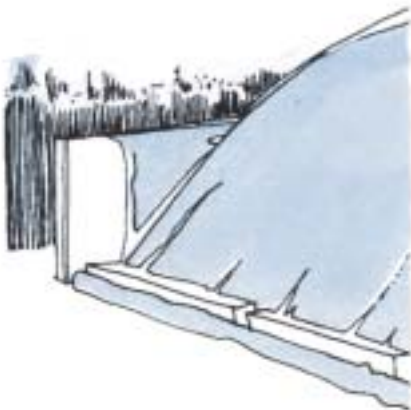
Contents

1	Foreword
2	Why Bulk Storage?
2	Why Store Salt Properly?
2	How Much Salt Do You Need?
3	Order Salt Early
4	Select the Right Site
6	How Much Space Will It Occupy?
8	Put It On a Pad
9	Put It Under Cover
13	Delivery Tips
13	Work Safely
13	Communicate
13	General Safety Rules
13	Belt Conveyor and Screw Conveyor Safety Rules

14	Electrical Safety Rules
14	Summary
15	Storage Area Checklist
17	Appendix
	Standard Specification for Sodium Chloride
	A Rapid Test Method for Sodium Chloride

Inside Back Cover

Metric to English and
English to Metric
Conversion Chart



Foreword

Salt has been used for thousands of years as a food preservative and a taste enhancer. It is essential to human nutrition. Today it has additional functions in food processing and is also used in animal nutrition, in water softening and in industry. The chemical industry uses it to make chlorine and caustic soda that, in turn, are used to produce hundreds of products. One of the principal uses of salt is for deicing of streets and highways to assure safe driving conditions. Use of salt and plowing prevents 7 of every 8 crashes that would occur on untreated snow and ice-covered winter roadways.

Approximately 33 million tons of dry salt are produced each year in the United States and Canada. Some 15-25 million tons of it are used as deicing salt, the largest single usage.

Salt has been used since the 1940s as a major weapon in combating ice and snow on streets and highways. Today nearly all agencies responsible for winter maintenance in the United States and Canada use salt as one of the major tools to remove snow and ice quickly from roads.

Salt prevents the bonding of ice and snow to pavement surfaces, permitting more efficient and faster removal of hazardous snow and ice. Mostly, salt is used in conjunction with plowing. Without salt, snowplows cannot completely remove snow and ice from road surfaces.

On ice, and in cases where snow isn't deep enough, or where it isn't practical to plow, salt often is used alone.

Salt is the ideal deicing material because:

- * It is readily available
- * It is inexpensive
- * It is easy to store and handle
- * It is easy to spread
- * It is non-toxic and harmless to skin and clothing
- * It is harmless to the environment when used and stored properly.

Many deicing salt users are making every effort to ensure protection of the environment through proper storage and application practices, something we call Sensible Salting.

Salt is abundant in the earth and the sea. However, getting it where it is needed and on time has become more difficult with today's necessity for year-round mobility. The availability of ships, barges, railcars and trucks, the time of ordering and the weather itself all play an important role in salt delivery.

Good storage facilities with adequate capacity can go a long way toward guaranteeing sufficient salt when it is needed to maintain a high level of winter maintenance for the safety and mobility of motorists and the unimpeded movement of goods and services. Because salt is so vital, proper storage must be provided to protect it from the elements and to protect the environment. Good storage becomes even better with proper housekeeping around storage areas.

We hope this manual will help you in planning or improving your salt storage facilities and provide guidance for good storage and handling procedures.



Why Bulk Storage?

Why should a public works agency use proper bulk salt storage facilities?

There are three answers - economy, availability and convenience.

Bulk salt is the most economical deicing material available. Initial cost is low. Handling and storage are simple. Spreading is fast and easy.

Salt never loses its ice melting power no matter how long it is stored or how old it is. Salt is already millions of years old when it is mined. Each year thousands of tons of salt are stored and carried over to be used the next year. It is just as effective as though freshly mined or harvested. Neither is there any loss to moisture from the air if salt is stored properly. Salt does not absorb moisture until the humidity exceeds 75 per cent. Moisture that is absorbed will later evaporate, but there may be a thin crusting on the surface of the stockpile that is easily broken up.

Salt, however, can be lost to precipitation. Stockpiles, whether large or small, should never be left exposed to the elements - rain or snow. Storage should always be done on impermeable pads, either in a building or covered with one of the many types of temporary covering materials, such as tarpaulin, polyethylene, polyurethane, polypropylene or Hypalon. These materials are also available with reinforcement for added strength. Proper storage inside a building or under cover will also prevent possible detrimental effects on the environment. When salt is stored outside, runoff must be properly controlled.



Why Store Salt Properly?

Properly stored salt will:

- * Prevent formation of lumpy salt that is difficult to handle with loaders and to move through spreaders,
- * Eliminate the possibility of contaminating streams, wells or groundwater with salt runoff,
- * Eliminate the loss of salt by runoff and dissolving by precipitation.

Anticaking Additives. The best way to prevent or minimize caking is to store salt under cover. Most salt producers add anticaking agents. However, if left exposed to weather, anticaking agents can be washed from the outer layer of salt.

Crushers. Avoid the necessity to use crushers to get rid of lumps in salt by storing salt under cover where anticaking agents will not be washed out and crusting will be minimal. Crushers are not always readily available and they can be costly.

Adequate bulk storage assures enough salt to fight winter storms, without the problem of arranging emergency shipments throughout the winter months.



How Much is Needed?

Order enough. Ideally, there should be storage room for at least 100% of the estimated average winter's salt requirements.

It is wise to take early delivery of winter supplies and store the material until it is needed. Suppliers do their best to maintain deliveries and service salt users from strategically located stockpiles. However, replenishment of salt stockpiles becomes difficult during heavy demand periods, such as during back-to-back winter storms. It is always best to keep your sheds full to eliminate large backlogs of orders at stockpiles, speeding deliveries.

How Much Salt Will Be Needed This Winter?

Estimating future salt requirements is tough. Few public works officials ever hit the figure right on the nose. Here are a few guidelines for estimating future salt needs:

1. Never reduce last winter's figure simply because you hope next winter will be milder. Make realistic estimates based on average needs over the previous five or ten-year period.
2. Be sure to take into account new mileage added to your road or street system. Don't overlook new subdivision streets, Interstate or express highways and routes acquired from other political subdivisions.



3. Improve winter maintenance operations. Going to straight salt, including applying liquid brine or pre-wet solids, or adding more salt routes can substantially influence salt requirements while providing a higher level of service.

Serious consideration should be given to the possibility of unseasonably cold temperatures, blizzard conditions, prolonged cold spells and unusually large amounts of snow. All of these conditions, though unpredictable, will affect your use of salt one way or the other.

Use the chart below to figure approximate salt needs for your area.

Order Salt Early

Plan your salt program early. Summer is best. Remember that your purchasing process can impose waiting periods between the time bid notices are advertised and a supplier is selected. Start your procurement process to allow sufficient time to take pre-season delivery.

Work with your salt supplier to take delivery in the summer or fall, taking advantage of logistics factors in your supplier's supply chain. Early delivery is generally better. It ensures a ready supply and allows your supplier to prepare a suitable stock point in your area. Salt cannot be transported up the Mississippi River, for example, once the waterways are frozen and winter closes most Great Lakes ports.

Should in-season re-supply be required, re-order before on-hand inventories are depleted. Check inventory levels frequently and always before a forecasted storm.

TABLE 1: SALT REQUIRED PER SEASON

SHORT TONS/METRIC TONS
Based on 4 applications per storm Per 2-lane Mi/Km

Number of Storms	Two Lane Highway on Bare Pavement							
	Mi Km	100	200	300	400	500	600	700
4		400	800	1200	1600	2000	2400	2800
		363	724	1089	1452	1814	2177	2540
6		600	1200	1800	2400	3000	3600	4200
		544	1089	1633	2177	2722	3266	3810
8		800	1600	2400	3200	4000	4800	5600
		726	1452	2177	2903	3629	4355	5080
10		1000	2000	3000	4000	5000	6000	7000
		907	1814	2722	3629	4536	5443	6350
12		1200	2400	3600	4800	6000	7200	8400
		1089	2177	3266	4355	5443	6532	7621
14		1400	2800	4200	5600	7000	8400	9200
		1270	2540	3810	5080	6350	7621	8346
16		1600	3200	4800	6400	8000	9600	10200
		1452	2903	4355	5806	7258	8709	9253
18		1800	3600	5400	7200	9000	10800	11600
		1633	3266	4899	6532	8165	9798	10524
20		2000	4000	6000	8000	10000	12000	14000
		1814	3629	5443	7258	9072	10886	12700



Select the Right Site

The most critical step in providing good storage is selecting the storage site. S-A-L-T-E-D is the key word in picking the right spot.

Safety - Always make safety for workers and the general public a prime concern at a storage site. Equipment operators need good visibility in all directions. Access roads should not open directly into heavily traveled routes. Post signs to warn motorists that trucks enter and leave the area. Make sure the area is secure, preferably fenced, to prevent entrance by unauthorized persons. Children can be attracted by salt piles, which could be dangerous for them. It is also essential to secure the area in such a way as to provide safety for the surrounding environment.

Make it safe!

Accessibility - Storage sites should permit easy access by trucks and other equipment entering and leaving these areas during storms, when visibility is low. Plan accordingly.

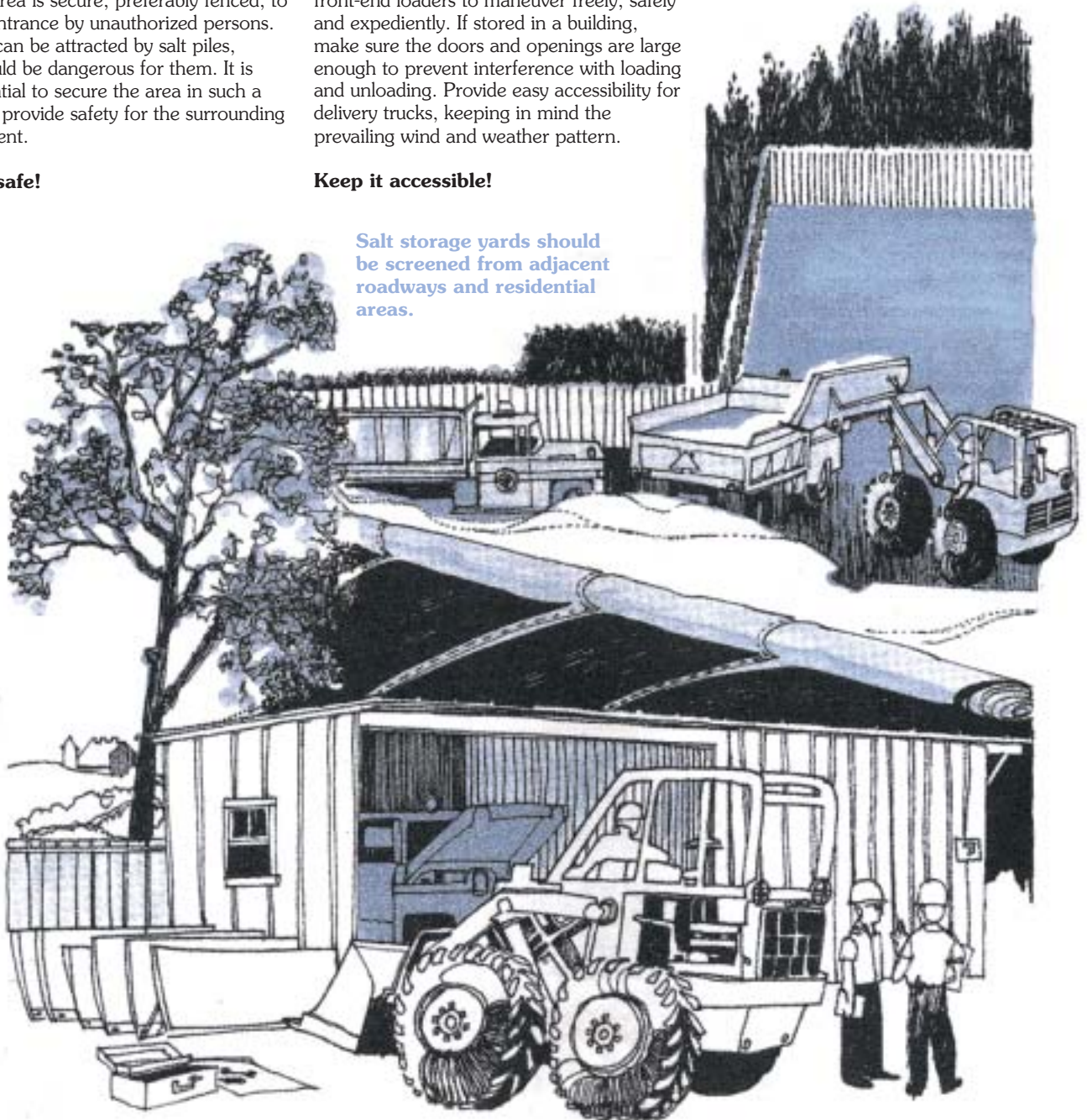
The storage area must be large enough for front-end loaders to maneuver freely, safely and expediently. If stored in a building, make sure the doors and openings are large enough to prevent interference with loading and unloading. Provide easy accessibility for delivery trucks, keeping in mind the prevailing wind and weather pattern.

Keep it accessible!

Legality - You must comply with local zoning requirements, as well as local, state and federal regulations governing environmental discharge concerns.

Keep it legal!

Salt storage yards should be screened from adjacent roadways and residential areas.



Tidiness - Make storage facilities blend with local surroundings when possible, especially in residential areas. They should be well kept, with no junk or scrap material piled around that would give an impression of sloppiness or waste and allow the possibility of getting foreign objects in spreaders.

“Live” fences offer an attractive alternative to chain link or wood.

Salt spilled during delivery or loading must be cleaned up and returned to the storage structure as soon as possible.

Be a good neighbor. Keep it tidy!

Economics - Locate and distribute storage facilities so that empty trucks don't have to “dead-head” long distances to reload. This reduces operating costs and speeds up spreading operations.

Permanent covered storage is a good method. Unprotected piles waste salt and could be harmful to the environment.

Keep it economical!

Drainage - Locate all storage structures to provide good drainage away from the stockpile. Pads should have a slope of 1/4 inch per foot away from the center. Pads, aprons and other adjacent work areas should be capable of supporting the stockpile and equipment.

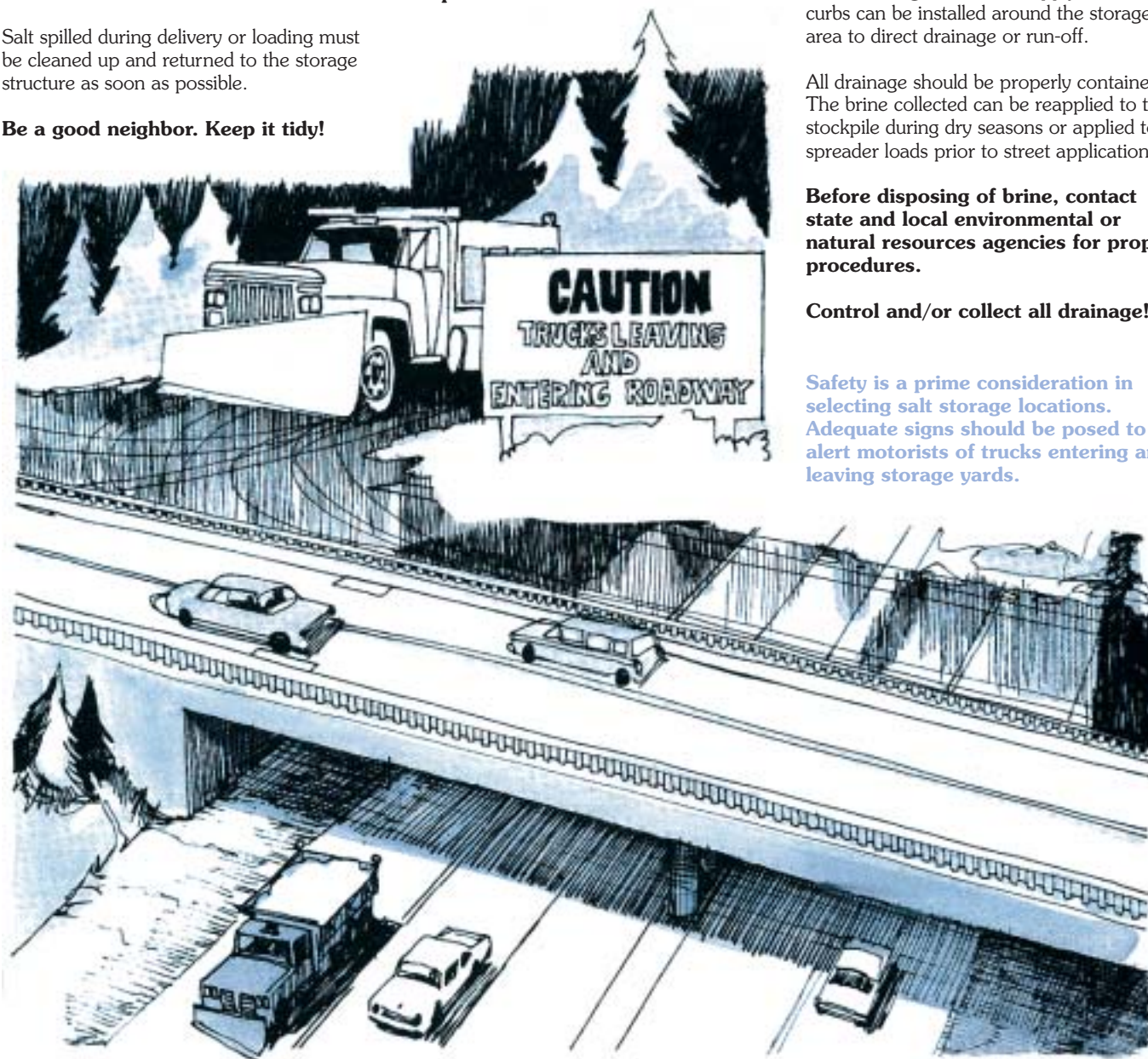
Ensure that your storage area does not accidentally drain into a freshwater reservoir, well or groundwater supply. If needed, curbs can be installed around the storage area to direct drainage or run-off.

All drainage should be properly contained. The brine collected can be reapplied to the stockpile during dry seasons or applied to spreader loads prior to street applications.

Before disposing of brine, contact state and local environmental or natural resources agencies for proper procedures.

Control and/or collect all drainage!

Safety is a prime consideration in selecting salt storage locations. Adequate signs should be posed to alert motorists of trucks entering and leaving storage yards.



How Much Space Will It Occupy?

There is a limit to how much salt you can store in a given area. From certain facts about salt's physical characteristics, we can determine in advance how much space a known amount will occupy.

When deicing salt falls freely into a pile, it forms a cone with sides that slope at an angle of 32 degrees, salt's natural angle of repose. Other types and gradations of salt have slightly different angles of repose but are within one or two degrees.

The density of deicing salt ranges from 72 pounds per cubic foot loose to 84 pounds compacted. When calculating storage space requirements, use the figure 80 pounds per cubic foot (equivalent to 1281.4 kg/m³).

When using 80 pounds per cubic foot, a cubic yard of salt weighs 2,160 pounds. Thus, a ton of salt would require 25 cubic feet of storage space (equivalent to 21.06 m³/metric ton of salt).

All calculations in this publication are based on a density for salt of 80 pounds per cubic foot.

Space requirements in Stockpiles. It is possible to calculate the area requirements of any cone-shaped salt stockpile, since the slope of the pile is known.

Table 2 lists characteristics of conical salt piles containing varying amounts of salt. For example, look at the column for 1,000 tons of salt and read across to the right. This much salt, stored in a cone-shaped pile, will occupy a space 67'1" in diameter, or 3,540 square feet. The pile's height will be 21 feet and the length of its slope from ground to peak 40 feet. Volume of the pile would be 25,000 cubic feet. It would have an exposed surface area of 4,180 feet (important if you wanted to cover the pile and needed to know how much polyethylene, canvas or other covering material to order).

It is also possible to calculate the dimensions required for salt stored in a windrow shape with conical ends. Table 3 shows how much salt may be stored per running foot in windrows of various heights. Width requirements are also shown. For example, 2.4 tons of salt may be stored per running foot of a windrow-shaped pile with a base 19'4" wide and a height of six feet.

TABLE 2: STORING SALT IN CONICAL PILES

Salt Short Tons metric tons	Diameter of Pile ft m	Space Occupied by Pile ft ² m ²	Height of Pile ft m	Length of Slope from Ground to Peak ft M	Volume of Pile In ft ³ m ³	Exposed Surface Area ft ² m ²
24	19.33	295	6.0	11	600	339
21.8	5.89	27.41	1.83	3.35	17.00	31.49
50	24.67	479	8.0	15	1,250	565
45.7	7.52	44.50	2.44	4.57	35.38	52.49
80	28.92	655	9.0	17	2,000	773
72.6	8.81	60.85	2.74	5.18	56.60	71.81
100	31.17	765	10.0	18	2,500	904
90.7	9.50	71.07	3.05	5.49	70.75	83.98
200	39.33	1,213	12.5	23	5,000	143.2
81.4	11.99	112.69	3.81	7.01	141.50	133.3
300	45.00	1,595	14.0	27	7,500	1,877
272.2	13.72	148.18	4.27	8.23	212.25	174.37
400	49.42	1,916	15.5	29	10,000	2,260
362.9	15.06	178.00	4.72	8.84	283.00	209.95
500	53.33	2,240	17.0	32	12,500	2,640
453.6	16.25	208.10	5.18	9.75	353.75	245.26
600	56.67	2,530	18.0	34	15,000	2,980
544.3	17.27	235.04	5.49	10.36	424.50	276.84
700	59.58	2,790	18.5	35	17,500	3,290
635.0	18.16	259.19	5.64	10.67	495.25	305.64
800	62.33	3,050	19.5	37	20,000	3,610
725.8	19.00	283.35	5.94	11.28	566.00	335.37
900	64.83	3,310	20.5	38	22,500	3,900
816.5	19.76	307.50	6.25	11.53	636.75	362.31
1,000	67.08	3,540	21.0	40	25,000	4,180
907.2	20.45	328.87	6.40	12.19	707.50	383.32
2,000	84.50	5,620	26.5	50	50,000	6,630
1,814.4	25.76	552.10	8.08	135.24	1,415.00	615.93
3,000	96.83	7,380	30.5	57	75,000	8,710
2,721.6	29.51	685.60	9.30	17.37	2,122.50	809.6
4,000	106.50	8,880	33.5	63	100,000	10,470
3,628.8	32.46	824.95	10.21	19.20	2,830.00	972.66
5,000	115.00	10,370	36.0	68	125,000	12,230
4,536.0	335.05	963.37	10.97	20.73	3,537.50	1,136.17
6,000	122.00	11,700	38.5	72	150,000	13,810
5,443.2	37.19	1,086.93	11.73	21.95	4,245.00	1,282.95
7,000	128.33	12,960	40.5	76	175,000	15,290
6,350.4	39.11	1,203.98	12.34	23.16	4,952.50	1,420.44
8,000	134.17	14,130	42.0	77	200,000	16,680
7,257.6	40.90	1,312.68	12.80	24.05	5,660.00	1,549.57
9,000	139.83	15,400	44.0	83	225,000	18,170
8,164.8	42.62	1,430.66	13.41	25.30	6,367.50	1,687.99
10,000	144.67	16,410	45.5	85	250,000	19,370
9,072.0	44.10	1,524.49	13.87	25.91	7,075.00	17,911.47

TABLE 3: STORING SALT IN WINDROWED PILES

Salt in Each Running Foot/Meter of Windrow

short tons metric tons	Width ft m	Height ft m	Exposed Surface Volume ft ³ m ³	Area ft ² m ²
2.4	19.3	6.0	59	23
2.18	5.89	1.83	1.67	2.14
3.8	24.7	8.0	96	29
3.45	7.52	2.44	2.72	2.69
5.2	28.9	9.0	131	34
4.72	8.81	2.74	3.71	3.16
6.3	31.1	10.0	158	37
5.72	9.50	3.05	4.47	3.44
9.7	39.3	12.5	243	46
8.80	11.99	3.81	6.88	4.27
12.7	45.0	14.0	318	53
11.52	13.72	4.27	9.00	4.92
15.3	49.4	15.5	383	58
13.88	15.06	4.72	10.84	5.39
17.9	53.3	17.0	447	63
16.24	16.25	5.18	12.65	5.85
20.2	56.67	18.0	505	67
18.33	17.27	5.49	14.30	6.22
22.3	59.58	18.5	557	70
20.23	18.16	5.64	15.76	6.50
24.4	62.3	19.5	610	74
22.14	19.00	5.94	17.26	6.87
26.3	64.83	20.5	657	77
23.86	19.76	6.25	18.60	7.15
28.3	67.1	21.0	708	79
25.67	20.45	6.40	20.04	7.34
44.8	84.5	26.5	1,120	100
40.64	25.76	8.08	31.70	9.29
58.8	96.83	30.5	1,470	114
53.34	29.51	9.30	41.60	10.59
771.2	106.50	33.5	1,780	126
64.59	32.46	10.21	50.37	11.71
83.2	115.00	36.0	2,080	136
75.48	35.05	10.97	58.86	12.63
93.6	122.0	38.5	2,340	144
84.91	37.19	11.73	66.22	13.38
103.6	128.33	40.5	2,590	151
93.99	39.11	12.34	73.30	14.03
113.2	134.2	42.0	2,830	158
102.70	40-90	12.80	80.09	14.68
122.8	139.8	44.0	3,070	165
111.4.0	42.62	13.41	80.88	15.33
131.6	144.67	45.5	3,290	171
119.39	44.10	13.67	93.11	15.89.

Table 3 gives the capacity only for the windrow section of the pile. Figure the dimensions of the cone-shaped end sections from Table 2.

Space requirements in buildings. To figure how much space will be required to store salt in a bin or building, divide the weight in pounds of salt to be stored by 80 to obtain the number of cubic feet required and deduct the amount of space lost due to the slope of the pile at the front of the building.

The amount of storage space that cannot be used due to salt's "angle of repose" will depend upon the height of the pile and the width of the building. Here are some typical calculations:

TABLE 4

Height of Pile ft m	Width of Bay ft m	Deduct This Amount short tons metric tons
8	12	24.4
2.44	3.66	22.14
10	12	38.2
3.05	3.66	34.66
12	12	54.9
3.66	3.66	49.81
15	12	85.8
4.57	3.66	77.84
20	12	152.6
6.10	3.66	138.44

$H \times H \times W \times 0.0318 =$ Lost Tonnage due to Angle of Repose

Thus, storage capacity of a building 30 ft wide and 40 ft deep, with salt piled ten ft high, would be 384 tons.

$$\frac{30 \times 40 \times 10 \times 80}{2000} - (10 \times 10 \times 30 \times 0.0318) = 384 \text{ Tons}$$



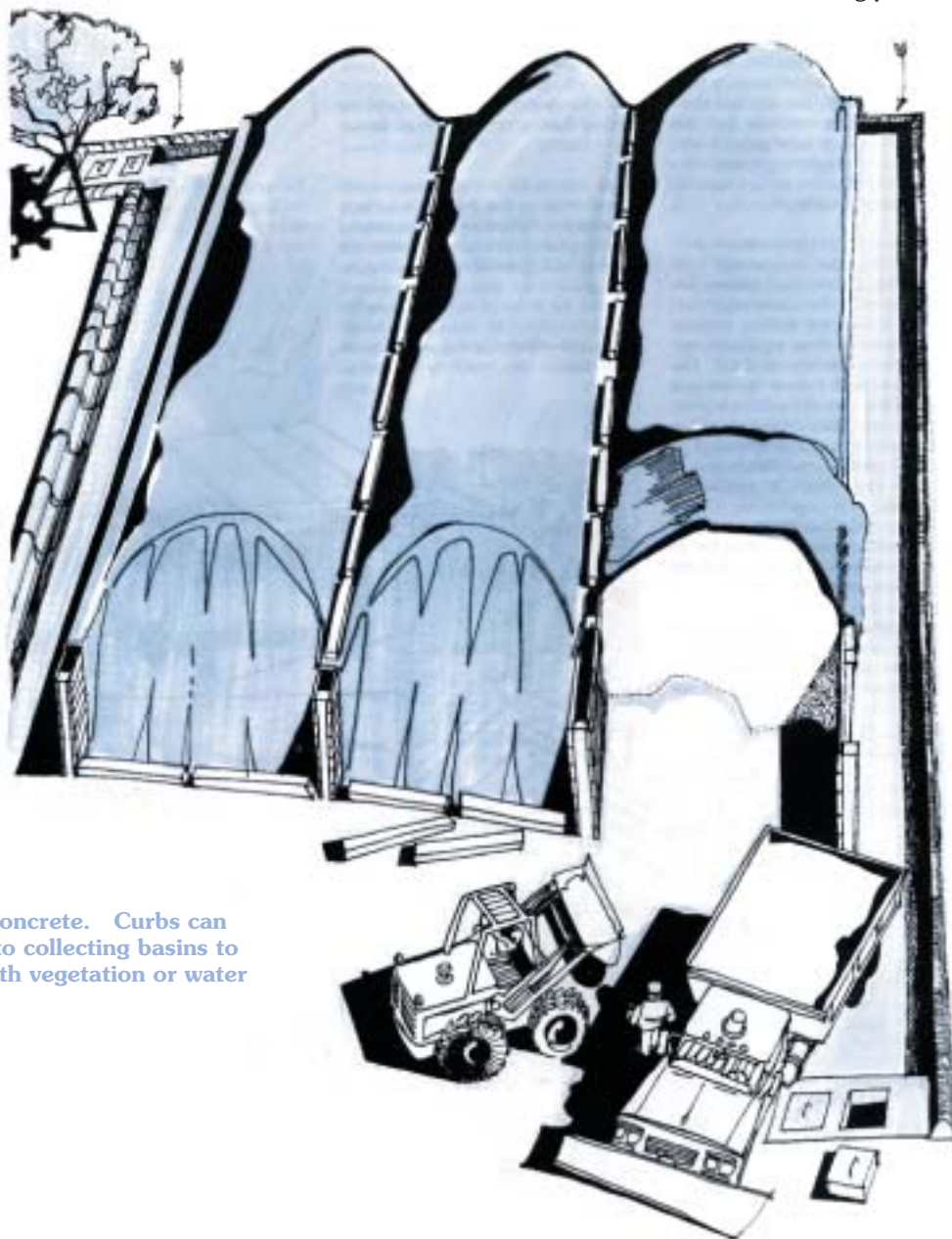
Put It On A Pad

Permanent, covered storage is recommended, particularly for small piles which are not actively managed. It is also acceptable to store salt in outdoor stockpiles on bituminous or concrete pads. This low-cost method provides maximum storage space and easy access. Whether stored inside or outside, salt always should be on a pad. If outdoor storage is used, it must be properly covered.

The pad site should be located away from wells, reservoirs and groundwater supplies. If pads are constructed of concrete, they must be high quality, air-entrained and treated with sealants, asphaltic-type coatings, or other treatments to keep salt out and prevent spalling. Total thickness of surface and base for asphalt pads will vary, depending upon the condition of the subgrade and weight to be supported. Any asphalt surfacing material used by highway departments is satisfactory.

Slope pads to let surface water drain away. Let local conditions control the direction of slope to avoid excessive grading. Minimum slope is one to two per cent. For good drainage, install ditches, pipes and tile where necessary. In some cases, it may be necessary to install pipes, tiles or asphalt berms to channel water to a collection point, preferably a specially designed sump area.

Pads may later be framed on three sides to form a bin, or storage buildings may be erected over existing pads.



Curbing asphalt or concrete. Curbs can direct salt run-off into collecting basins to prevent problems with vegetation or water supplies.

Put it Under Cover

Salt stored in bins or on pads outdoors may be covered with a variety of materials, including:

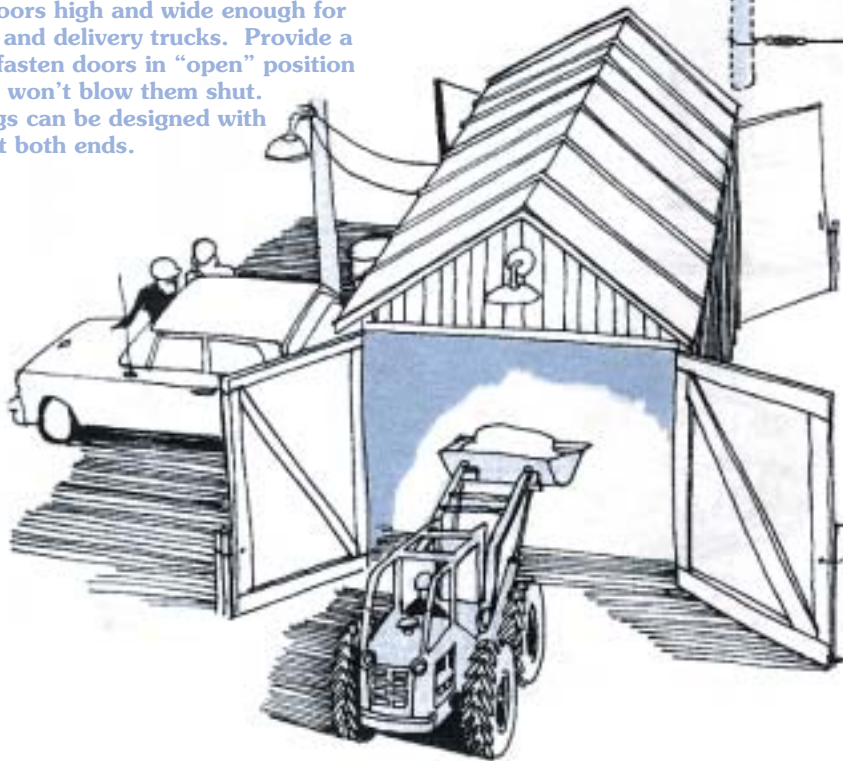
- * Polyethylene
- * Polypropylene
- * Hypalon
- * Polyurethane foam
- * Water-resistant canvas
- * Any other suitable waterproof cover (All of the above may be reinforced for added strength).

To join flexible coverings, lap and sew together with a two-inch standing seam, using a sewing machine suitable for such purpose. This gives a relatively waterproof and durable seam for most of these coverings. Taping of sewn seams improves waterproofing.

Industrial adhesive tapes may also be used to join coverings but sewing is preferable.

Old tires (which are unacceptable in some places) or sand bags lashed together with rope or cable and placed uniformly over the flexible cover provide a suitable tie-down weighting method. Also available for tying covers are poly-cord nets. Be sure to weight down the base of the cover to keep wind from peeling covers off salt piles. Timbers or sand may be used.

Make doors high and wide enough for loaders and delivery trucks. Provide a way to fasten doors in "open" position so wind won't blow them shut. Buildings can be designed with doors at both ends.



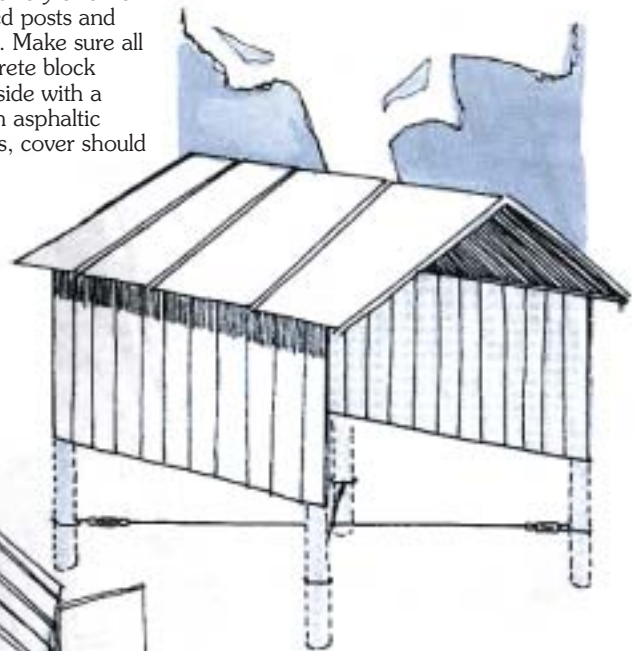
A good method for covering smaller piles of deicing salt is the ground level storage shed or building. Storage structure size will vary with individual needs. There are as many types of storage buildings as there are ideas. Many agencies have developed their own particular style. Most buildings, of course, are let for bid, but there are also many that are built with spare or used materials and the agency's own labor.

Various pre-fabricated buildings are available. If building your own, storage buildings may be constructed of pressure treated timbers, assorted lumber, old bridge timbers and decking, concrete blocks, corrugated sheet metal or a variety of other materials on hand. Use treated posts and timbers in pole-type buildings. Make sure all hardware is galvanized. Concrete block buildings should be treated inside with a suitable sealant or coated with asphaltic material. In case of open ends, cover should be supplied for exposed salt.

A good, properly drained pad is just as important when salt is stored in a building as when stored on an open pad.

Doors on buildings must be high and wide enough to permit easy access by front-end loaders and delivery trucks. Door openings should be a minimum of 20 feet wide. Hinge doors to allow fastening in the "open" position so that high winds won't hinder operations.

Tie corner posts of storage buildings together with underground galvanized cables with turnbuckles.



Make sure any overhang in front of the building does not complicate truck unloading or loading.

Areas around the building must be well lighted. Inside of buildings, place lights to the side and high to keep from covering wiring or light fixtures with salt when the building is full to avoid corrosion damage.

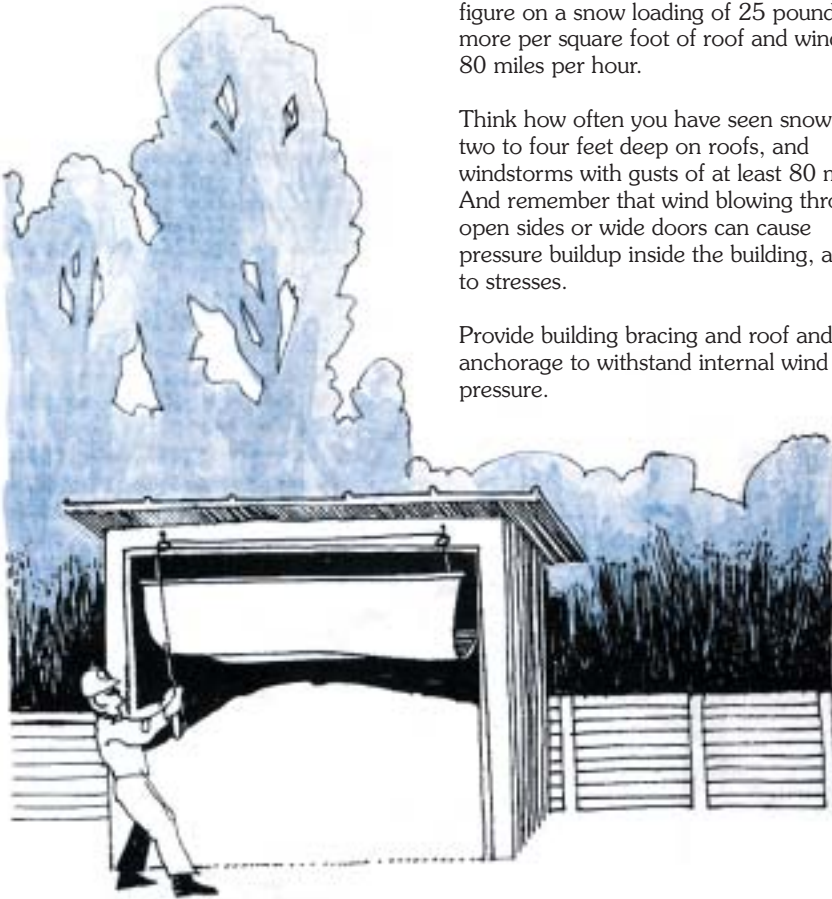
Painting the inside of the storage facility with light-colored or white paint will enhance light reflectance, provide maximum visibility and may be a very worth-while expense.

Build it strong

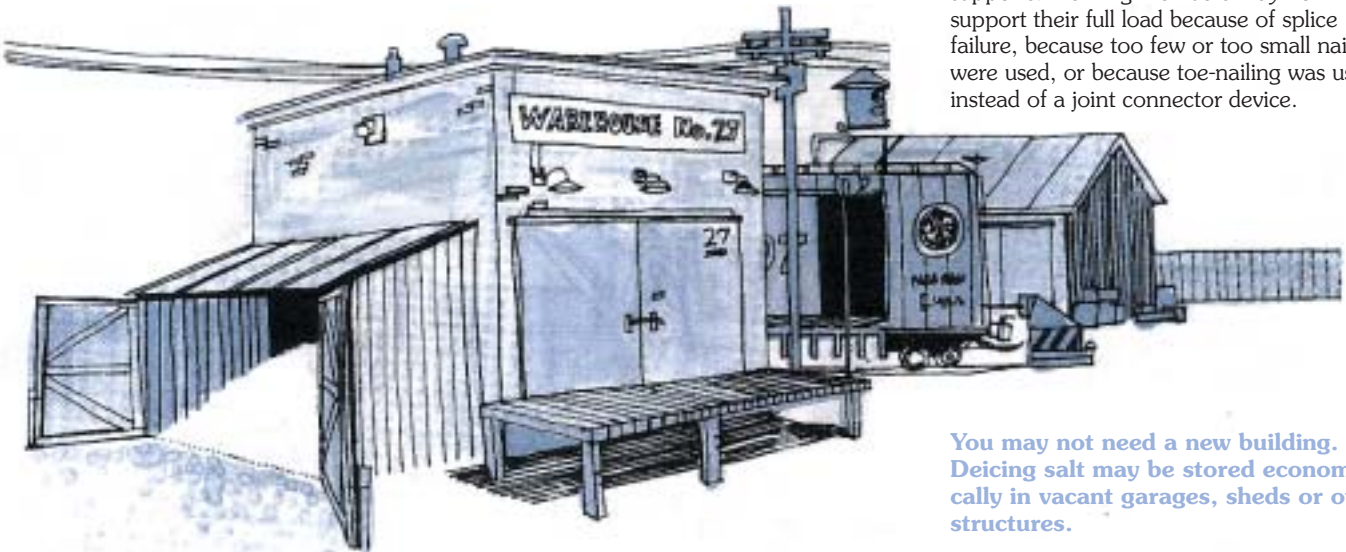
Wind and snow are enemies of storage buildings. For adequate building design, figure on a snow loading of 25 pounds or more per square foot of roof and winds of 80 miles per hour.

Think how often you have seen snow piled two to four feet deep on roofs, and windstorms with gusts of at least 80 mph. And remember that wind blowing through open sides or wide doors can cause pressure buildup inside the building, adding to stresses.

Provide building bracing and roof and wall anchorage to withstand internal wind pressure.



Provide pull-down cover for open-end storage buildings; one method is shown here.



The following design considerations should be taken into account to allow for effects of wind and snow:

1. Location and Arrangement - Trees and other barriers may help shield a building against strong winds and snow, but putting a building too near a tree line may cause snow to accumulate around the building.
2. Foundation and Anchorage - Buildings tend to move with the wind; strong winds can lift a roof or collapse a wall. Buildings must be anchored securely to resist these pushing and lifting forces. Common mistakes are failing to anchor sills securely to foundations and using poles that are too small, too far apart or not embedded deeply enough.

A general guide is to embed sound, pressure-treated poles four feet or more into undisturbed soil or set in concrete. Use closer pole spacings, heavier poles and deeper embedment for very high pole buildings.

3. Construction practices - Poor construction causes many building failures. Knee bracing may be skimpy, building crossies poorly located, joints poorly fastened or framing members too small.

Whole roof and wall sections may blow off as a unit because a building literally comes apart at the seams. Common failures occur when rafters give way at plate lines, building corners become detached, or purlin and nailing girts are pulled loose from their supports. Framing members may not support their full load because of splice failure, because too few or too small nails were used, or because toe-nailing was used instead of a joint connector device.

You may not need a new building. Deicing salt may be stored economically in vacant garages, sheds or other structures.

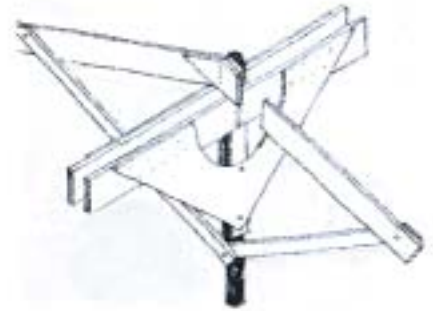
4. Building Materials - Lumber defects, such as knots or splits, may cause main supports to fail, especially under heavy snow weight. Failure of a weak member means adjacent members have to support more load, leading to their failure.

Allow adequate tie-down for fastening rafters to purlins. This is typical bracing. Rafters and purlin sizes will vary with building sizes and pole spacing during construction.

Wind damage to corrugated sheet metal is common. Sheets come loose because of too few nails, poor anchorage or nail heads pulling through. Use 90 to 100 screw shank nails per 100 square feet of corrugated steel roofing. One-half to two-thirds of the nail should be embedded in the support member.

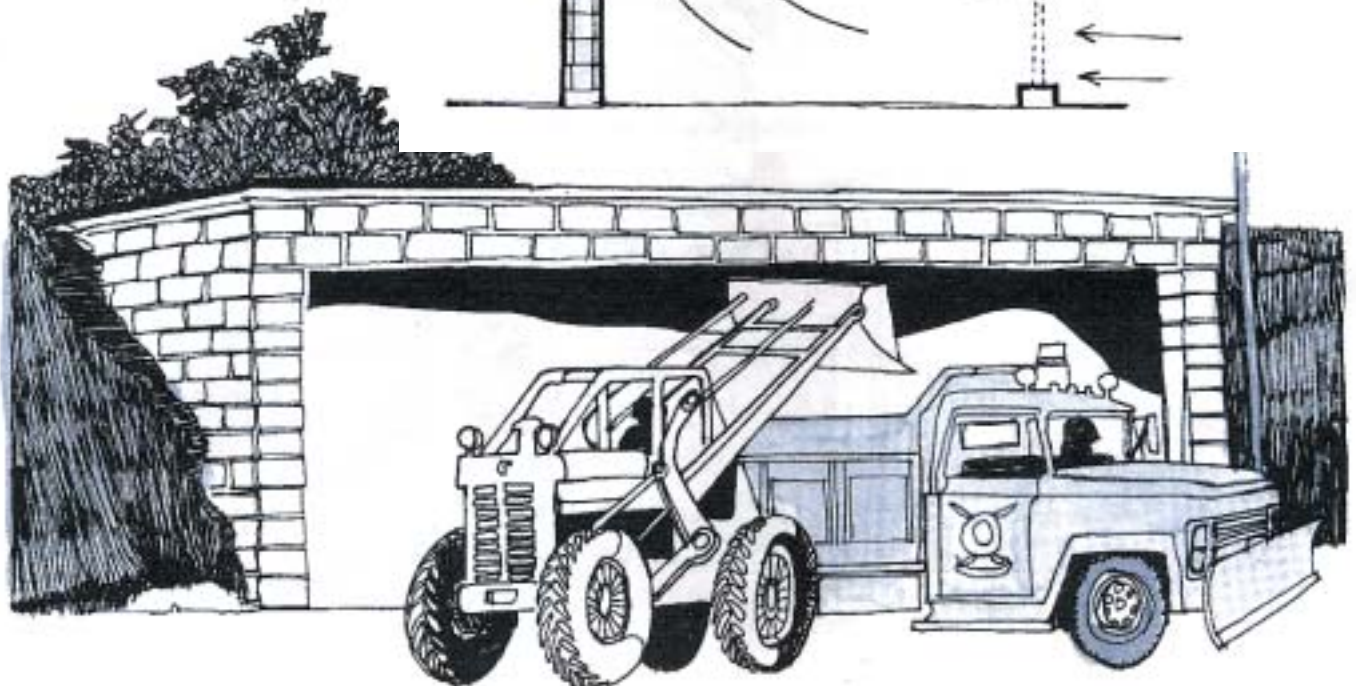
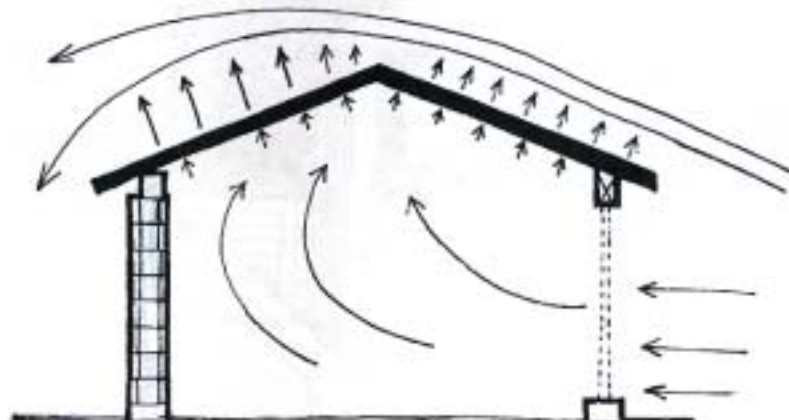
Use only exterior type plywood for sheathing, gusset plates, braces, doors and other building parts exposed to moisture and weathering.

Building and bin walls must withstand pushing from front-end loaders and pressure from stored salt. This calls for deep embedment of poles or proper construction of concrete block sides. Exterior bracing or earthen support may be



To anchor sills, use 1/2-inch anchor bolts 16 inches long. 12-inches deep in 6- or 8-inch poured concrete foundation. Space not over 5 feet. Use 1 3/4-inch round washers; two 2 x 4- or two 2 x 6-inch members for sill.

Diagram shows effect of wind blowing into open doors of a salt storage building.



required to prevent loaders from pushing the walls out. The salt alone creates some pressure on the walls, but the loader adds to the pressure when forcing its way into the pile. Another way to lessen pressure on outside walls is to build an interior bulkhead.

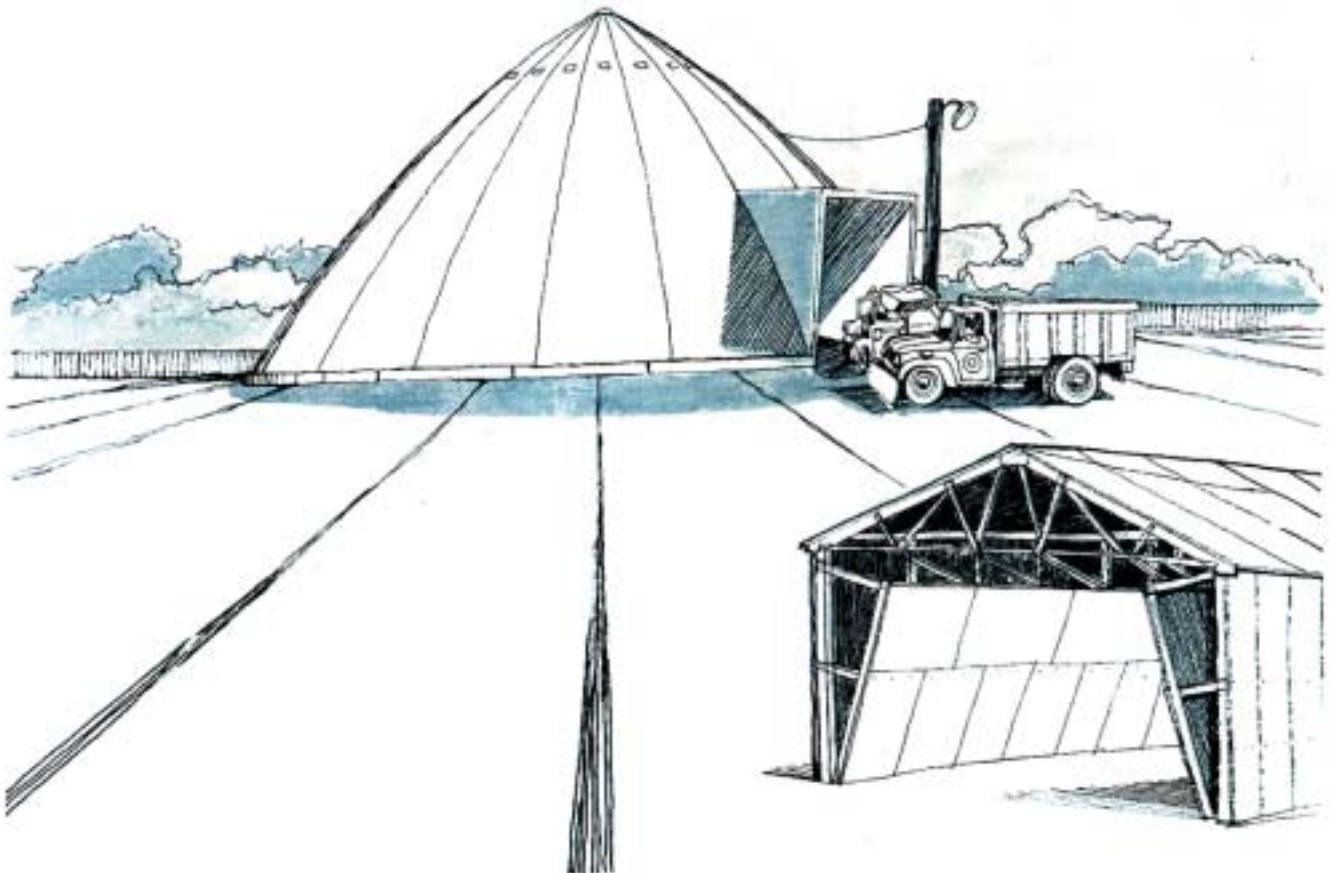
From the floor up, the pressure wall framing should be covered with 2" x 12" boards, which protect the supports from damage by loader buckets. Outside shed walls should be tongue-and-groove carsing. The roof should be of half-inch plywood topped with 90 pound roll roofing mineral surface.

Vehicle exhaust fumes can become obnoxious or hazardous if the storage facility is not properly ventilated. Sufficient ventilation must be provided to permit operation of a front-end loader and possibly a spreader truck in the case of large under-roof storage facilities. Forced ventilation should be installed in any building with a door opening smaller than the total width of the structure.

Receiving Salt

Shape the pile properly. For covered outside storage on a pad, the stockpile should be windrowed with well-sloped sides so all water will drain off and away from the pile. Ease of re-covering during the course of the winter should be considered in determining the height and overall size of the pile.

For in-building storage facilities, the most common method of filling is by dumping the salt directly in front of the building and pushing it inside with front-end loaders. Conveyors are sometimes used. Slingers, short conveyor belts capable of throwing the salt some distance, are used by some trucking firms. Use of either of these types of equipment requires sufficient volume in order to justify the cost of use. Where conveyors are installed in buildings, support structures and loadings should be carefully evaluated to avoid structural overloading and possible damage or failure. Taller structures (17 plus ft.) are now being built that will allow trucks to empty their load inside the building.



Delivery Tips

No matter how you store salt, it will likely be delivered to the site by truck. There are several ways to speed delivery.

Allow enough room for maneuvering.

The average length of large trailer trucks that deliver deicing salt is 48 feet. Some are 55 feet long.

Room for turning and backing should be at least twice the length of the longest delivery truck entering the site.

When dumping, trailer beds may rise 30 feet above ground level. Allow for this when planning the front of storage buildings and when locating power lines and lights.

Provide enough support for heavy equipment. Large trailer trucks weigh up to 80,000 pounds when fully loaded. Total thickness of the pads and base in storage areas served by large loaders and trucks will vary, depending upon the condition of the subgrade.

Help truckers find the spot. A hard-to-find storage site may slow salt delivery. Place signs indicating locations of salt storage points and furnish maps and directions to truckers.

Don't keep truckers waiting. If a storage facility is properly designed, a truckload of bulk salt can be unloaded in three or four minutes. But truckers often stand idle waiting for someone to authorize delivery. These delays can be costly.

Generally, shipments cannot be unloaded unless a delivery ticket is signed. Make sure someone is available to accept and authorize deliveries.

Post names and telephone numbers of persons responsible for receipt of deliveries at storage areas.

Watch what you get. Salt is tested by suppliers for shipping weight. It is supplied in accordance with ASTM specification D-632, which is shown on page 17 and 18. If additional tests are necessary, try to make them quickly, using standardized equipment and procedures.

All trucks should be tarped with a secure cover during transit to prevent sifting, loss of salt and to keep salt dry.

The same trucks that deliver salt may haul other materials. Such foreign objects may damage spreaders and could occasionally get into salt.

Play it safe. Maintenance personnel should stay clear of the rear of trucks at all times. Night deliveries require special precautions. Clearly mark entrances to the storage site. Make sure yards and inside of storage facilities are adequately lighted. Place lights and wiring out of reach of raised truck beds and loaders.

Work Safely

Not only is Safety the #1 listed concern in our S-A-L-T-E-D summary, worker safety merits additional suggestions to support a safe work environment.

Communicate

Open and forthright channels of communication need to be established and maintained between employees and supervisors, and between employees. Employees must be encouraged to take responsibility for their own safety and participate in all efforts to improve the overall safety of the facility. Employees must be able to report to management any unsafe or questionable environmental condition without fear of reprisal, and must be encouraged to make recommendations to correct and improve those concerns. Employees must be provided with opportunities to attend safety meetings and task training to improve their knowledge, and encouraged to participate in the facility's safety program. Management must act as a role model by adhering to all environmental, safety, and health rules and all regulatory requirements governing the site.

General Safety Rules

Salt storage facility employees need to adhere to general industrial safety rules. These include:

- * Inspect mobile equipment for hazards and determine safe operating condition before use.

- * Do not operate equipment or perform new tasks until properly trained by a qualified person.
- * Wear appropriate personal protective equipment to protect against the hazards that exist in the work area. Wear seatbelts when operating mobile equipment.
- * Always "lock, tag and test" any equipment before you attempt to repair or troubleshoot.
- * Follow required work practices and permit systems for electrical repairs or confined space entry.
- * Immediately report all unsafe acts or conditions to a supervisor or manager. Immediately report any work related incident, injury or illness to your supervisor.
- * Practice good housekeeping by keeping assigned work areas clean and orderly.
- * Do not smoke in and around lubricant storage sites or refueling vehicles.

Salt Stockpile Safety Rules (Rules apply whether stockpile is inside or outside a building)

- * Never approach the vertical face of a stockpile on foot or in a vehicle closer than the vertical dimension of the pile; it might collapse and cover you in an avalanche.
- * Never park next to a stockpile or next to loaders or other equipment working a stockpile.
- * Never position yourself between the face of a stockpile and an immovable object (such as a loader or other vehicle).
- * When working on top of a stockpile, never approach the crest closer than 15 feet.
- * Always ensure that you have proper footing when accessing the top of a stockpile, and always be alert for sinkholes or other openings in the surface of the pile.

Belt Conveyor and Screw Conveyor Safety Rules

- * Employees must be especially careful when operating and working around conveyors - especially when in close proximity to head and tail pulley, idler pulleys, and take-up pulleys.

- * Conveyors must be equipped with emergency stop devices or pull cords. These emergency stop devices and pull cords must be checked regularly to ensure they are in working order.
- * Conveyors must never be operated unless all guards are in place and securely fastened. Screw conveyors must never be operated unless top covers are in place and secured.
- * Employees must never walk on top of a screw conveyor. Employees must never step onto or ride an operating conveyor belt.
- * Before making repairs to a conveyor, it must always be de-energized and then locked, tagged and tested to ensure that it will not start unexpectedly. Employees must never attempt to apply belt dressing, or to lubricate an operating conveyor, unless protected by guards and a remote system has been installed to facilitate these procedures.

Electrical Safety Rules

- * Only employees who are properly trained should be allowed to work on electrical equipment.
- * Employees must be alert for electrical hazards and make an immediate report to their supervisor when electrical hazards are identified.
- * Always treat de-energized electrical equipment and conductors as energized until lockout/tagout, grounding, and testing procedures are implemented to verify a zero energy state.
- * Determine the reason for fuse and breaker trips before resetting circuits.

Summary

The proper storage of salt is extremely important. Protection of salt and the surrounding environment, and ease of handling salt, are necessary and can be ensured through proper storage of salt either under roof or by covering outside stockpiles.

Street and highway maintenance agencies should make a continuous effort to provide good salt storage. Good storage also must include proper maintenance of facilities and good housekeeping practices.

Storage capacity for 100% of your average winter's needs can help eliminate the need for delivery during critical storm periods and will ensure that salt is available when needed.

Good planning is essential to good storage and proper storage is a vital part of Sensible Salting.



Storage Area Checklist

This sample storage area checklist can be used to keep a record of all your salt storage facilities, their capacities, their condition, and additions or improvements needed. It can also be used to record your estimated salt requirement, salt in stock and salt on order. The form is shown merely as a guideline.

Storage Identification _____				
Estimated Salt Requirement _____				
Salt in Stock _____				
Salt on Order _____				
Facilities Available			Facilities Needed	
Total Number: _____ <small>(Specify pad, bin, building, other)</small>	Capacity <small>(tons)</small>	Condition	Total Number: _____ <small>(Specify pad, bin, building, other)</small>	Capacity <small>(tons)</small>
Remarks:				

Storage Area Checklist (continued)

This part of the form provides a checklist for safety features, proper access, legality, tidiness, economics and drainage.

Yes	No	SAFETY. . .
<input type="checkbox"/>	<input type="checkbox"/>	1. Equipment operators have good visibility in all directions.
<input type="checkbox"/>	<input type="checkbox"/>	2. Access roads do not open directly into heavily traveled routes.
<input type="checkbox"/>	<input type="checkbox"/>	3. Signs are posted to warn motorist that trucks enter and leave the area.
<input type="checkbox"/>	<input type="checkbox"/>	4. Culvert headers, guard rails and other obstructions in storage area are marked so they can be avoided when covered with snow.
<input type="checkbox"/>	<input type="checkbox"/>	5. Outside areas are adequately lighted.
<input type="checkbox"/>	<input type="checkbox"/>	6. Lights are available inside storage buildings.
<input type="checkbox"/>	<input type="checkbox"/>	7. Storage yards are free of junk and other debris.
<input type="checkbox"/>	<input type="checkbox"/>	8. All mechanical parts of storage facility, such as hinges, slides, conveyors, are in safe working condition.
<input type="checkbox"/>	<input type="checkbox"/>	9. All mechanical equipment is in safe working condition.

Comment—

ACCESS. . .

<input type="checkbox"/>	<input type="checkbox"/>	1. Spreader trucks can easily enter and leave storage sites, even during periods of low visibility.
<input type="checkbox"/>	<input type="checkbox"/>	2. Storage areas are large enough for front-end loaders and trucks to maneuver.
<input type="checkbox"/>	<input type="checkbox"/>	3. Building doors and other openings are large enough to permit loading and unloading.
<input type="checkbox"/>	<input type="checkbox"/>	4. There are no low and weak spots in storage yard.

Comment—

LEGALITY. . .

<input type="checkbox"/>	<input type="checkbox"/>	1. All storage areas are on state or municipal property or on space for which there is a definite lease rental or use agreement.
<input type="checkbox"/>	<input type="checkbox"/>	2. All storage sites comply with local zoning ordinances and applicable building, environmental, discharge and sanitation codes.

Comment—

TIDINESS. . .

<input type="checkbox"/>	<input type="checkbox"/>	1. Storage yard is well maintained and clean.
<input type="checkbox"/>	<input type="checkbox"/>	2. Junk or scrap material is not piled around yards.
<input type="checkbox"/>	<input type="checkbox"/>	3. Storage sites are shielded from view of nearby roads or homes by plantings or fencing.

Comment—

ECONOMICS. . .

<input type="checkbox"/>	<input type="checkbox"/>	1. Storage is covered to prevent loss of material.
<input type="checkbox"/>	<input type="checkbox"/>	2. Sites are strategically located to avoid deadheading to reload.

Comment—

DRAINAGE. . .

<input type="checkbox"/>	<input type="checkbox"/>	1. Storage pads are on sites with proper drainage.
<input type="checkbox"/>	<input type="checkbox"/>	2. Storage runoff is properly contained, collected and provisions made for use or disposal.

Comment—

Appendix/Salt Specification

When ordering, specify sodium chloride as ASTM Designation: D632 or AASHTO M143. Do not specify year so the current specification will automatically be followed.

AASHTO Designation M143 complies with ASTM D-632.

Standard Specification for Sodium Chloride: ASTM Designation D632-YEAR

This Standard is issued under the fixed designation D632; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers sodium chloride intended for use as a deicer and for road construction or maintenance purposes.

1.2 The values stated as SI units are to be regarded as the standard.

1.3 The following precautionary caveat pertains only to the test method portion, Section 9 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

C 136 Method for Sieve Analysis of Fine and Coarse Aggregates²

E 11 Specification for Wire-Cloth Sieves for Testing Purposes²

E 534 Methods for Chemical Analysis of Sodium Chloride³

3. Classification

3.1 This specification covers sodium chloride obtained from natural deposits (rock salt) or produced by man (evaporated, solar, other) and recognizes two types and two grades as follows:

3.1.1 Type 1 - Used primarily as a pavement deicer or in aggregate stabilization.

3.1.1.1 Grade 1- Standard gradation (Note 1).

3.1.1.2 Grade 2 - Special gradation (Note 1).

3.1.2 Type 11- Used in aggregate stabilization or for purposes other than deicing.

Note Grade 1 provides a particle grading for general application, and found by latest research to be most effective for ice control

and skid resistance under most conditions. Grade 2 is the grading typical of salt produced in the western U.S. and available in states of the Rocky Mountains Region and west which may be preferred by purchasers in that area.

4. Chemical Requirements

4.1 The sodium chloride shall conform to the following requirement as to chemical composition:

Sodium Chloride (NaCl), min %, 95.0

5. Physical Requirements

5.1 Gradation:

5.1.1 Type 1- The gradation of Type 1 sodium chloride, when tested by means of laboratory sieves, shall conform to the following requirements for particle size distribution:

Sieve Size	Weight % Passing	
	Grade 1	Grade 2
19.0 mm (3/4 in.)	-	100
12.5 mm (1/2 in.)	100	-
9.5 mm (3/8 in.)	95 to 100	-
4.75 mm (No. 4)	20 to 90	20 to 100
2.36 mm (No. 8)	10 to 60	10 to 60
600 mm (No. 30)	0 to 15	0 to 15

5.1.2 Type 11-The gradation of Type II sodium chloride shall conform to the grading requirements imposed or permitted by the purchaser under conditions of the intended use.

6. Permissible Variations

6.1 In the case of sodium chloride sampled after delivery to the purchaser, tolerances from the foregoing specified values shall be allowed as follows:

6.1.1 Gradation-5.0 percentage points on each sieve size, except the 12.5 mm (1/2 in.) and 9.5 mm (3/8 in.) for grade 1 and 19.0 mm (3/4 in.) for grade 2.

6.1.2 Chemical Composition 0.5 percentage point.

7. Condition

7.1 The sodium chloride shall arrive at the purchaser's delivery point in a free-flowing and usable condition.

8. Sampling

8.1 Not less than three sample increments shall be selected at random from the lot (Note 2). Each increment shall be obtained by scraping aside the top layer of material to a depth of at least 25 mm (1 in.) and taking a 500-g (approximately 1-lb) quantity of sodium chloride to a depth of at least 150 mm (6 in.). Sampling shall be done by means of a sampling thief or other method which will assure a representative cross section of the material. The sample increments shall be thoroughly mixed to constitute a composite sample representative of the lot.

Note 2: A lot may be an amount agreed upon between purchaser and supplier at the time of purchase.

9. Test Methods

9.1 Chemical Test-Test for compliance with the requirements for chemical composition shall be in accordance with the following methods:

9.1.1 Routine Control -The "Rapid Method" provided in Annex A1 may be used for routine control and approval.

9.1.2 Referee Testing-In case of controversy, determine analysis in accordance with Methods E534.

9.2 Gradation shall be determined by Method C136.

10. Inspection

10.1 The purchaser or his representative shall be provided free entry and necessary facilities at the production plant or storage area if he elects to sample sodium chloride at the source.

11. Rejection and Rehearing

11.1 The sodium chloride shall be rejected if it fails to conform to any of the requirements of this specification.

11.2 In the case of failure to meet the requirements on the basis of an initial sample of a lot represented, two additional samples shall be taken from the lot and tested. If both additional samples meet the requirements, the lot shall be accepted.

12. Packaging and Marketing

12.1 The sodium chloride shall be delivered in bags or other container acceptable to the purchaser, or in bulk lots. The name of the producer and the net weight shall be legibly marked on each bag or container, or, in the case of bulk lots, on the shipping or delivery report.

13. Keywords

13.1 salt; snow and ice removal; sodium chloride; stabilization; winter maintenance.

¹This specification is under the jurisdiction of ASTM Committee D-4 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.31 on Calcium, Sodium Chlorides and Other Deicers.

²Annual Book of ASTM Standards, Vol 04.02.

³Annual Book of ASTM Standards, Vol 11.01.

⁴Annual Book of ASTM Standards, Vol 14.02.

⁵Annual Book of ASTM Standards, Vol. 14.04.

⁶Annual Book of ASTM Standards, Vol. 15.05.

⁷Reagent Chemicals, American Chemical Society, Washington, DC. For suggestions on testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and the National Formulary*, U.S. Pharmacopial Convention, Inc., (USPC), Rockville, MD.

⁸Supporting data have been filed at ASTM Headquarters, Request RR: D04.1016.

⁹These numbers represent respectively, the (I_s %) and (d_{2s} %) limits, as described in Practice C670.

ANNEX

(Mandatory Information)

A1 RAPID METHOD OF ANALYSIS FOR SODIUM CHLORIDE

A1.1 Scope

A1.1.1 This annex covers a rapid method for chemical analysis of sodium chloride.

A1.2 Significance and Use

A1.2.1 The procedure for chemical analysis in this annex determines the total amount of chlorides present in the sample and expresses that value as sodium chloride.

A1.2.2 This rapid method of analysis does not distinguish between sodium chloride and other evaporite chloride compounds with ice-melting capabilities. Typical rock salt and solar salt sometimes contains small amounts of CaCl_2 , MgCl_2 , and KCl , depending on the source of the material. When this rapid method is used on continuing shipments from a known source, it will provide a fast, essentially accurate determination of the sodium chloride content of the material furnished. Thus the need for testing by the referee method, Test Method E 534 is reduced.

A1.3 Apparatus

A1.3.1 *Glassware*—Standard weighing bottles, volumetric flasks (conforming to Specification E 288, Class B- or better), and burets (conforming to Specification E 287, Class B- or better).

A1.3.2 *Balance*, having a capacity of at least 20 g, accurate and readable to 0.01 g.

A1.4 Reagents

A1.4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.⁷ Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A1.4.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water as defined by Types I-IV of Specification D 1193.

A1.4.3 *Calcium Carbonate* (CaCO_3)—low chloride, powder.

A1.4.4 *Nitric Acid* (HNO_3)—dilute ($\text{HNO}_3:\text{H}_2\text{O}$, 1:4 by volume).

A1.4.5 *Potassium Chromate* (K_2CrO_4) Solution—(50 g $\text{K}_2\text{CrO}_4/\text{L}$).

A1.4.6 *Silver Nitrate Solution*—0.05 N AgNO_3 .

A1.4.7 *Sodium Chloride* (NaCl).

A1.5 Procedure

A1.5.1 Thoroughly mix the composite sample obtained under 8.1, and reduce by quartering or by means of a sample splitter to approximately 500 g. Pulverize the reduced sample to pass a 300 μm (no. 50) sieve.

A1.5.2 *Standardization*—Standardize the silver nitrate (AgNO_3) solution daily, using 10 g of reagent grade sodium chloride (NaCl) following the applicable procedure in A1.5.3.

A1.5.3 From the pulverized sodium chloride, obtain a test sample with a mass of 10.00 ± 0.01 g and place in a beaker with 250-mL distilled water. Add 10 mL of the diluted nitric acid solution (HNO_3 , 1 + 4 by volume) and stir for 20 min at room temperature to put the salt in solution. Transfer the solution, including any insoluble material, to a 2-L volumetric flask, dilute to the mark with distilled water, and mix. With a pipet, draw off 25 mL of the solution and place in a white porcelain casserole. Add 0.5 g of calcium carbonate (CaCO_3) to neutralize the excess HNO_3 , and adjust the pH to approximately 7. Add 3 mL of the potassium chromate (K_2CrO_4) solution as an indicator and titrate dropwise with the silver nitrate (AgNO_3) solution until a faint but distinct change in color occurs—a persistent yellowish brown endpoint (see Note A1.1), comparable to standardization. Estimate the titer from the buret to the second decimal place.

Note: A1.1—The stirred sample solution, after addition of potassium chromate (K_2CrO_4) and calcium carbonate (CaCO_3) is a creamy lemon-yellow color. Addition of the silver nitrate (AgNO_3) solution produces silver chloride, which begins to agglomerate as the titration progresses, and the lemon-yellow color will begin to have whitish opaque swirls of silver chloride. As the titration proceeds, the red color formed by addition of each drop begins to disappear more slowly. Continue the addition dropwise until a faint but distinct change in color occurs and the yellow-brown to faint reddish-brown color persists. The first stable presence of red silver chromate is the end point. If the endpoint is overstepped, a deep reddish-brown color occurs.

A1.6 *Calculate*—Calculate the total chlorides expressed as percent NaCl as follows:

$$P = [(A/B) \times (C/D)] \times 100 \quad (\text{A1.1})$$

Where:

A = reagent grade NaCl used, g,

B = 0.05 N AgNO_3 solution required to titrate the reagent grade NaCl , mL,

C = 0.05 N AgNO_3 solution required to titrate the sample being tested, mL,

D = test sampling mass, g, and

P = total chlorides expressed as sodium chloride in the sample being tested, %.

A1.6.1 If moisture is apparent in the sample, dry a duplicate 10-g sample of the pulverized salt at 105°C and correct the mass of the sample accordingly.

A1.7 Precision and Bias

A1.7.1 *Precision*⁸—An interlaboratory study was conducted and an analysis was made that included three materials ranging from approximately 92 to 99 % NaCl . Ten laboratories were included in the study.

A1.7.2 *Single-Operator Precision* (NaCl composition 95.0 % and greater)—The single-operator standard deviation of a single test result for average NaCl composition 95.0 % and greater has been found to be 0.248.⁹ Therefore, results of two properly conducted tests by the same operator on the same material with the same equipment and under the same conditions should not differ by more than 0.70 %.⁹

A1.7.3 *Multilaboratory Precision* (NaCl composition 95.0 % and greater)—The multilaboratory standard deviation of a single test result for average NaCl composition greater than 95.0 % has been found to be 0.633 %.⁹ Therefore, results of two properly conducted tests in different laboratories on the same material should not differ by more than 1.79 %.⁹

A1.7.4 *Single Operator Precision* (NaCl composition 95.0 % and greater than 90.0 %)—The single-operator coefficient of variation of a single test result for average NaCl composition less than 95.0 % and greater than 90.0 % has been found to be 0.427 %.⁹ Therefore, results of two properly conducted tests by the same operator on the same material with the same equipment and under the same conditions should not differ by more than 1.21 %.⁹

A1.7.5 *Multilaboratory Precision* (NaCl composition less than 95.0 % and greater than 90.0 %)—The multilaboratory standard deviation of a single test result for average NaCl composition less than 95.0 % and greater than 90.0 % has been found to be 0.711 %.⁹ Therefore, results of two properly conducted tests in different laboratories on the same material should not differ by more than 2.00 %.⁹

A1.7.6 *Bias*—No justifiable statement can be made on the bias of this test method because the data are not available.

American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards.

Reprinted with permission of ASTM. This standard is copyrighted by ASTM, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax) or service@astm.org (e-mail); or through the ASTM website (www.astm.org).

English/Metric Conversion Chart

METRIC TO ENGLISH

Multiply When You Know	English by	to Find	Symbol
millimeters	0.0394	inches	in
centimeters	0.394	inches	in
meters	3.281	feet	ft
meters	1.0936	yards	yds
kilometers	0.6214	miles	mi
square centimeters	0.1550	square inches	sq in
square meters	10.7639	square feet	sq ft
square meters	1.1959	square yards	sq yds
hectare	2.4711	acres	
square kilometers	0.3861	square miles	sq mi
cubic centimeters	0.0611	cubic inches	cu in
cubic meters	35.3147	cubic feet	cu ft
cubic meters	1.3078	cubic yards	cu yds
milliliters	0.0338	ounces (fluid)	oz
liters	2.1135	pints (fluid)	pts
liters	1.0567	quarts (fluid)	qts
liters	0.2641	gallons	gals
liters	1.8162	pints (dry)	pts
liters	0.9081	quarts (dry)	qts
cubic meters	28.3776	bushels	bu
grams	0.0352	avoirdupois ounces	avdp oz
kilograms	2.2046	avoirdupois pounds	avdp lbs
metric tons (2204.6 lbs)	1.1023	short tons (2000 lbs)	tn
metric tons	0.9842	long tons (2240 lbs)	t

(Celsius temperature x 1.8) + 32 = Fahrenheit temperature

ENGLISH TO METRIC

Multiply When You Know	Metric by	to Find	Symbol
inches	25.4	millimeters	mm
inches	2.54	centimeters	cm
feet	0.3048	meters	m
yards	0.9144	meters	m
miles	1.609	kilometers	km,
fathoms	1.8	Meters	m
square inches	6.4516	square centimeters	cm ²
square feet	0.0929	square meters	m ²
square yards	0.8361	square meters	m ²
acres	0.4047	hectares	ha
square miles	2.5899	square kilometers	km ²
cubic inches	16.3871	cubic centimeters	cu ³
cubic feet	0.0283	cubic meters	M ³
cubic yards	00.7645	cubic meters	m ³
ounces (fluid)	29.5737	milliliters	mL
pints (fluid)	0.4732	liters	L
quarts (fluid)	0.9463	liters	L
gallons	3.7853	liters	L
pints (dry)	0.5506	liters	L
quarts (dry)	1.1012	liters	L
bushels	0.0352	cubic meters	m ³
bushels	35.2381	liters	L
avoirdupois ounces	28.3495	grams	g
avoirdupois pounds	0.4536	kilograms	kg
short tons (2000 lbs)	0.9072	metric tons (2204.6 lbs)	t
long tons (2240 lbs)	1.0160	metric tons	t

(Fahrenheit temperature - 32) x 0.5555 = Celsius temperature



Salt Institute

700 North Fairfax Street, Suite 600
Alexandria, VA 22314-2040
Telephone 703-549-4648
Fax 703-548-2194
e-mail: info@saltinstitute.org
<http://www.saltinstitute.org>