

Physical Properties of Potash Products: Quality Control Procedures and Their Importance

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ABSTRACT

The potash producers of Saskatchewan manufacture several types of potassium chloride and potassium sulfate products for agricultural and industrial uses. Each product is characterized by a set of specifications defined in terms of chemical and physical properties. The physical properties of these products, like those of other solid fertilizers, are defined by parameters that include particle size distribution, size guide number, uniformity index, abrasion resistance, true density, apparent density, porosity, caking tendency, critical relative humidity, and dustiness. These parameters are determined according to specified procedures and equipment.

This paper identifies the quality control procedures used to measure the physical properties of potash products and the reason for their use.

INTRODUCTION

In recent years, product quality has become an increasingly dominant factor for Saskatchewan's potash producers competing in virtually stagnant and saturated agricultural export markets. As with other fertilizers, the quality of potash products is defined by their chemical and physical properties, which are measured by using specified procedures and equipment. These properties are used as direct and indirect quality control tools in the manufacture of potash products not only to improve the quality of existing products but also to design new products so that changing needs for potash products in both the agricultural and industrial sectors are better served. The chemical properties of potash products are expressed in terms of potassium chloride (KCl), potassium sulfate (K₂SO₄), potassium oxide (K₂O), and minor and trace amounts of certain compounds and elements. The terms that define the most important physical properties of potash products include particle size distribution (PSD), size guide number (SGN), uniformity index (UI), abrasion resistance, true density, apparent density, porosity, caking tendency, critical relative humidity (CRH), and dustiness.

This paper identifies quality control procedures most commonly related to the physical properties of

potash products, the use of these procedures in the production of potash products in Saskatchewan, and the reason for their use. It also suggests benefits to be derived by both producer and consumer when procedures are standardized and universally accepted by potash producers.

A SYNOPSIS OF POTASH MANUFACTURING IN SASKATCHEWAN

In Saskatchewan, potash is mined from one of the world's richest and largest deposits of sylvinites (KCl·NaCl) with total resources estimated at approximately 67 billion tonnes K₂O (The British Sulphur Corporation Limited, 1984). The ores contain an average of about 45% KCl (Pepper and Strathdee, 1986). The ores are mechanically mined by the Potash Corporation of Saskatchewan Inc. (PCS) at four mines, by the International Minerals and Chemicals Corporation at two mines, and by Central Canada Potash Company Ltd., and Cominco Ltd., each with one mine. At Kalium Canada Ltd. (Kalium) and the Potash Corporation of America Inc. (PCA), potash ores are solution mined.

Mechanically mined ores are hoisted to the surface and fed into the refinery where the conventional process consists of ore beneficiation and product pre-

paration phases. The beneficiation phase consists of several stages including crushing and grinding of ores to the potassium chloride liberation size and mechanical scrubbing to detach the slimes from the potassium chloride particles. The beneficiation phase also includes a separation stage in which potassium chloride is separated from a mixture of potassium chloride and sodium chloride either by froth flotation or by heavy media separation, after which the float is debrined mainly by centrifugation. The product preparation phase includes drying, screening, compaction/granulation, product conditioning, and a crystallization process. With mechanically mined ores, the crystallization process is normally a secondary production line to increase overall recoveries in the refinery, and in some cases to produce potash products with higher chemical grade.

The crystallization process becomes a primary production line both in the absence of ore beneficiation, in which case potassium chloride is leached directly from the mechanically mined ores, and with some solution mining operations. Depending on its function in the refinery, the crystallization process may include stages such as screening, compaction/granulation, and conditioning. The number and type of stages are therefore site specific (Eatock, 1985).

The solution mining method involves dissolution of the ore in subterranean cavities. Through a closed loop, the impregnated liquor is brought to the surface. At Kalium the impregnated liquor is fed into a series of evaporators to precipitate sodium chloride, which then is removed. The remaining saturated liquor is fed in a crystallization process which also includes a surface pond to precipitate potassium chloride. At PCA the impregnated liquor is fed into relatively shallow surface ponds to precipitate potassium chloride, which is then dredged and fed into the surface refinery for further processing. (Goldsmith and Klein, 1989; Smith, 1989).

Big Quill Resources Inc. uses a continuous ion exchange unit to produce potassium sulfate from fertilizer-grade potassium chloride and lake brine containing sodium sulfate. The resultant solution contains potassium sulfate, which is precipitated by salting-out and by cooling in a series of atmospheric crystallizers. The relatively small production of potassium sulfate, which is to be expanded to 7,200 t/year, is geared for specialized industrial applications (Big Quill Resources Inc., 1991).

CHEMICAL PROPERTIES

Chemical properties of potassium chloride are defined in terms of K_2O and KCl content, along with minor and trace compounds and elements. Similarly,

the chemical properties of potassium sulfate are characterized in terms of K_2O and K_2SO_4 as well as minor and trace compounds and elements. The required chemical purity is dictated by the end use of the potassium product. In the chlor-alkali industry, for example, even traces of certain contaminants in the potassium chloride are highly undesirable. Potassium sulfate products used in wall board manufacturing require very low levels of chloride. Lower levels of impurities are required in other specialized industrial applications such as the munitions industry. Because the procedures for determining the main chemical properties of potash products have been, in general, uniform and consistent throughout the industry, no attempt is made to describe them. Most of these procedures are described in the "Official Methods of Analysis" (The Association of Official Analytical Chemists, 1990). Methods requiring state-of-the-art technology like X-ray fluorescence equipment have also been adopted by some producers. Chemical properties are used more frequently as a monitoring and control tool in the production of products with higher purity. Thus, chemical properties are used and relied upon more frequently with crystallization circuits. Methods of controlling the purity of crystallized products have been described elsewhere (Goldsmith and Klein, 1989).

PHYSICAL PROPERTIES

Physical properties such as PSD, SGN, UI, abrasion resistance, true density, apparent density, and porosity are used throughout the product preparation stages as process control parameters. However, PSD, SGN, UI, and abrasion resistance are also of significance to marketing. These and properties like caking tendency, CRH, and dustiness serve the stages in which untreated potash products are prepared for distribution to distant markets. The physical characteristics, methods of determination, significance of these properties, and their function as monitoring and control tools in the manufacture of potash products will be described further. Emphasis is on potassium chloride production and products.

PRODUCT SIZE

The particle size distribution of various process streams is monitored throughout the refinery when manufacturing a specified product. Determining PSD involves simple procedures. Moreover, it is a relatively quick process and requires relatively inexpensive equipment comprising a set of sieves and a mechanical shaker. The procedures are applied throughout the industry and resemble closely the

TABLE 1
Typical product specifications of granular potassium chloride products

		Particle size distribution						K ₂ O (%)	H ₂ O (%)
Mesh, Tyler	Equivalent sieve opening ^a (mm)	+6	+8	+10	+14	+20	+28		
		(3.35)	(2.36)	(1.70)	(1.18)	(0.85)	(0.60)		
		(cumulative wt %)							
SGN/UI									
260/40	Range	5-15	55-75	85-95	96-99	98-100			
	Typical	10	65	90	98	99	60.9	0.15	
240/39	Range	5-15	45-65	82-93	96-99	98-100			
	Typical	10	52	87	98	99	60.8	0.07	
225/40	Range	0-5	35-55	80-90	96-99	98-100			
	Typical	3	45	85	98	99	60.4	0.15	
225/33	Range	3-9	40-55	80-90	93-98	95-98	97-100		
	Typical	6	45	85	94	97	98	60.4	0.15

^aAs specified by ISO 565, Test sieves — Woven metal wire cloth and perforated plate — Nominal sizes of apertures.
Source: PCS Sales, 1991.

general procedures outlined in the International Fertilizer Development Center's (IFDC) *Manual for Determining Physical Properties of Fertilizer* (Rutland, 1986). In the product preparation stages, PSD is used principally to monitor and control both the particle size in crystallizer circuits and the efficiency of the screening stages. Further, the use of PSD extends to feeds to compactor units because the PSD of these feeds exerts a considerable influence both on the efficiency of the overall compaction/granulation process and on the hardness of the untreated product. In at least one refinery, the determination of PSD was decentralized to various local areas in the refinery in contrast to being performed in a centralized laboratory, which is the norm in the industry.

Particle size distribution is particularly important for granular products designed mainly for bulk blending. The PSD of a specific potassium chloride product must be closely matched to the PSD of the other blending materials (like phosphates and nitrates) to prevent segregation in the blend and hence maintain uniform blend composition. When segregation occurs, it is caused by flow (coning), by ballistic action, or by vibrations principally because of differences in PSD. Other factors such as density and particle shape have secondary effects on segregation (Hoffmeister, 1979).

In addition to PSD, the size distribution of potassium chloride products designed for blending can be defined by two interrelated concepts, namely, the SGN and the UI. The SGN and UI were developed by

the Canadian Fertilizer Institute to simplify the technique of comparing size differences in raw materials. The SGN is the particle diameter at 50% cumulative mass weight. The UI is a ratio of the two extreme sizes of particles retained at 95% and at 10% levels multiplied by 100 (CFI, 1986). Thus, blend deficiencies are reduced when materials have closely matched SGN and UI values (Hester et al., 1989).

The PSD, SGN, and UI indices have been used by Canadian producers in developing products of larger particle size ranges, which more closely match the size of the predominant blending materials in the United States. This has placed additional pressure on existing compaction/granulation and flotation equipment to produce larger and more uniform potassium chloride particles. Products typically acceptable to bulk blenders are those having SGN of 225 to 260 and UI indices of 33 to 40 as shown in Table 1. The size distribution for coarse, standard, and fine products is shown in Table 2.

The PSD is used as a key property in the specification of specialty products for the industrial sector, such as untreated high-quality granular potassium chloride produced and marketed by both Kalium and PCS and the water softener-grade potassium chloride made at Kalium, as shown in Table 3. The size of some of the industrial grade potassium sulfate products is shown in Table 4. In general, Saskatchewan's potassium sulfate products are small in size and free of conditioning agents and have high chemical purity.

TABLE 2

Typical particle size distribution for coarse, standard, and fine potassium chloride products of Saskatchewan

Mesh, Tyler Equivalent sieve opening ^a (mm)	Particle size distribution											
	+6	+8	+10	+14	+20	+28	+35	+48	+65	+80	+100	+200
	(3.35)	(2.36)	(1.70)	(1.18)	(0.85)	(0.60)	(0.425)	(0.30)	(0.212)	(0.18)	(0.15)	(0.075)
	(cumulative wt %)											
Coarse												
SGN = 190												
Typical ^b (crystalline)	7	30	60	90	97	99						
Typical ^c		21	61	92	97							
SGN = 195 (pink)												
Typical ^b	5	30	65	94	97	98						
Standard												
SGN = 70												
Typical ^c			4	17	33	58	78	91	97			
SGN = 90												
Typical ^b (red)			30	55	80	90	96	98				
Fine												
SGN = 25												
Typical ^c						1	15	44	78	86	93	
SGN = 30												
Typical ^b (suspension)					8	20	50	70		90	98	

^aAs specified by ISO 565, Test sieves — Woven metal wire cloth and perforated plate — Nominal size of apertures.^bSource: PCS Sales, 1991.^cSource: Kalium Chemicals, 1991.

TABLE 3

Particle size distribution of untreated compacted products of potassium chloride for industrial use

Mesh, Tyler Equivalent sieve opening ^a (mm)	Particle size distribution									K ₂ O (%) NaCl (%)	
	+3/4	+1/2	+1/4	+4	+6	+8	+10	+14	+20		
	(19)	(12.5)	(6.3)	(4.75)	(3.35)	(2.36)	(1.70)	(1.18)	(0.85)		
	(cumulative wt %)										
High-quality granular grade											
Typical	2	18	60	73	83	91	95	97	98	62.65	0.7
Water softener grade											
Range	2-5	65-80	95-96	96-97	97-99					62.4	0.8

^aAs specified by ISO 565, Test sieves — Woven metal wire cloth and perforated plate — Nominal sizes of apertures.

Source: Kalium Canada Ltd., 1990.

ABRASION RESISTANCE

Abrasion resistance, commonly referred to among potash producers as product degradation, is measured on granular products to provide a relative indication of the hardness of a particular product.

The hardness reflects the ability of a product to withstand handling while in transit from the mine site to the end application. Conveying, overturning, stockpiling, blending, bagging, transporting, spreading, etc., cause abrasion between particles and between particles and equipment, resulting in product

TABLE 4

Particle size distribution and chemical specifications of potassium sulfate products produced in Saskatchewan

Mesh, Tyler Equivalent sieve opening ^a (mm)	Particle size distribution										K ₂ SO ₄ (%)	Cl (%)
	+14	+20	+28	+35	+48	+65	+100	+150	+200	(cumulative wt %)		
	(1.18)	(0.85)	(0.6)	(0.425)	(0.30)	(0.212)	(0.150)	(0.106)	(0.075)			
Wall board grade												
Range				0	5-20	25-50	50-70	65-80	80-90			
Typical				0	15	40	60	75	85	99.6	0.05	
Refined II												
Range		0-10	3-30	25-55	50-80							
Typical	2	10	50	90	97					99.9	0.003	
Refined IV												
Range						0-2	1-4	10-20				
Typical						0.5	1	15		99.9	0.002	

^aAs specified by ISO 565, Test sieves — Woven metal wire cloth and perforated plate — Nominal sizes of apertures.
Source: Big Quill Resources Inc., 1991.

degradation and the formation of residual dust, which can be directly related to the mechanical strength of the granules. Two test procedures (a rotary drum and a sieve method) for measuring resistance to abrasion are outlined in the IFDC manual (Rutland, 1986). The equipment and procedures endorsed by Saskatchewan Potash Producers Association (SPPA) to determine the hardness index of a product are detailed in Fig. 1. When the SPPA procedures and equipment are used, the portion of material that passes through a 20-mesh screen (<0.85 mm) defines the hardness index in percent of degradation.

During production, results from the abrasion resistance tests serve as an indirect monitoring and control tool for adjusting process variables (such as particle size distribution and temperature) in the compaction/granulation circuit to obtain a product of improved mechanical strength. After the material leaves the compaction/granulation circuit, the hardness of the granules can be further improved in a quenching/polishing stage. Water or process liquor is usually sprayed onto a stream of granular material, containing mostly compacted particles, just before the material enters a rotary drying drum. The quantity and the type of liquid and the tumbling time are determined and controlled on the basis of results from abrasion resistance tests. The abrasion resistance is also used to determine the aging effect on compacted products.

In order to estimate the effect that climatic conditions may have on product degradation, a modified

TABLE 5

Comparative information on abrasion resistance for compacted potassium chloride product samples exposed to accelerated climatic conditions

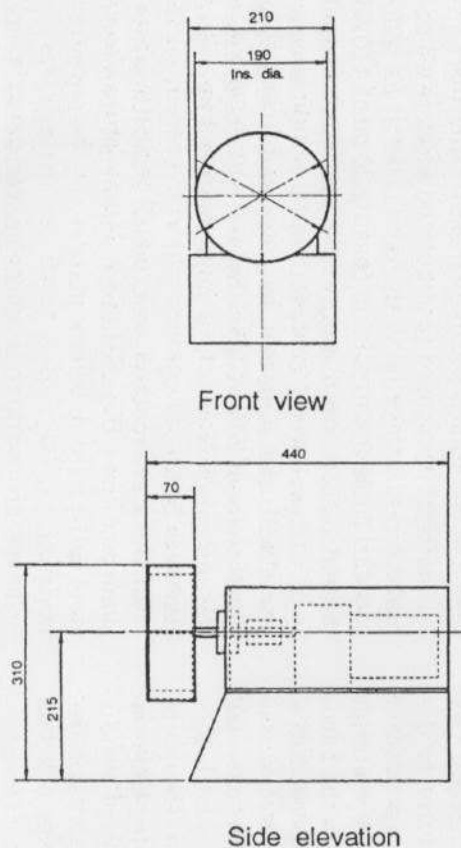
Relative humidity (%)	Product passing 20-mesh Tyler			
	A	B	C	D
	(wt % degradation)			
26	3.2	3.4	4.6	6.0
72	9.8	8.7	12.1	10.0

Source: Kalium Experimental Data.

abrasion resistance test is performed where granular material is exposed to simulated accelerated climatic conditions prior to the actual tests. As indicated in Table 5, the portion passing 20 mesh (<0.85 mm) increased substantially for a material exposed to an atmosphere of 72% relative humidity as compared with the same material exposed to a drying atmosphere of 26% relative humidity. In both cases the temperature was the same, and the exposure time was 24 h.

In the sieve-method test, which is still used by some producers, the abrading medium may comprise steel balls, steel rods, or a plate sitting on top of the material.

There are numerous abrasion resistance tests, developed mostly by the producers, which may give various abrasion resistance values on the same



Specifications

Pot size

190 mm inside diameter

64 mm wide

6 flights equally spaced @ 12 mm high

Pot @ 33.4 rpm

Front cover with 50 mm diameter hole for rubber stopper

Equipment

1. A stainless steel ball mill container, 7.5 inches in diameter by 2.5 inches wide with 6 flights equally spaced 0.5 inches high.

The ball mill is driven by a gear motor at 33.4 rpm.

2. 25 steel balls, 0.5 inches in diameter, total weight of 208.2 g. The balls should be stored in methanol when not in use to prevent rusting.
3. Tyler mesh screens full height stainless steel 8-mesh, 10-mesh, 20-mesh and a scalping screen larger than 8-mesh but smaller than 0.5 inches. These screens should be reserved for degradation tests and should be washed periodically to prevent buildup of reagents and potash.
4. Rotap shaker with hammer.
5. Automatic timer to start and stop equipment in a 5.0-min test interval.

Procedure

1. Split the representative potash sample to obtain 100-150 g of minus 8- plus 10-mesh material. Screen on the rotap with the hammer down using the 8- and 10-mesh screens for 5.0 min.
2. Weigh 100 g of the minus 8- plus 10-mesh product and transfer it to the ball mill container. It is essential that exactly 100 g of product ends up in the ball mill container.
3. Add the 25 steel balls.
4. Rotate for 5.0 min.
5. Transfer the contents of the ball mill container to the scalping screen. The scalping screen is placed on top of the 20-mesh screen.
6. Remove the scalping screen. Screen the contents of the 20-mesh screen on the rotap for 2.0 min with the hammer down.
7. Weigh the contents of the 20-mesh screen.
8. Calculate percent degradation = $100\% - \text{mass in grams of potash product retained on the 20-mesh screen}$.

Fig. 1. Equipment and procedures recommended by SPPA to determine the hardness index. Source: PCS Inc., 1992.

TABLE 6

Apparent density, true density, and porosity values of compacted potassium chloride products^a

Sample	Apparent density (g/cm ³)	True density (g/cm ³)	Mercury observed	Porosity (%)
A	1.99	2.00	None	0.5
B	1.98	2.00	None	1.0
C	1.97	2.00	Significant	1.5

^aDensity and Porosity Procedures (Rutland, 1986).

material. This was demonstrated by H. Rieschel and K. Zech of Maschinenfabrik Kopperrn GmbH and Company KG, Germany in evaluating the abrasion resistance of four potash samples with 12 different methods developed and utilized by various European and North American producers of potash. In one case, abrasion resistance values for one potash sample ranged from 3.93 to 70.31% (Rieschel and Zech, 1981). The multitude of methods employed in evaluating the same physical property demonstrates the need for international standard methods not only for abrasion resistance but also for other physical properties of potash products and fertilizers in general (Rutland, 1991b).

TRUE DENSITY, APPARENT DENSITY, AND POROSITY

Tests for the true density and apparent density of granules are used less frequently. As described in the IFDC manual (Rutland, 1986), they require special equipment to measure the volume of the granules. Apparent density measurement excludes the voids between granules. True density measurements exclude the voids between granules and the pores within the granule. The apparent density is based on the assumption that the viscous mercury used in the test is not absorbed into the pores of the granule. This assumption can be assessed by a visual inspection of the granule under a microscope. Variations of apparent densities can indicate excursions in granule hardness, moisture-holding capacity, and storage properties (Hoffmeister, 1979).

The porosity of the granules can be calculated, with some caution, by comparing the measured apparent density with the theoretical true density of pure potassium chloride (1.98 g/cm³). In compaction/granulation circuits, lower porosities generally reflect improved hardness of the granules and therefore a denser flake being produced in the compaction unit. In crystallized products, porosity may reflect

the particle growth conditions in the crystallizers. Typical apparent density and porosity values of compacted potassium chloride products are given in Table 6.

CAKING TENDENCY

The tendency of a fertilizer to cake is generally considered by most fertilizer manufacturers to be the most frequently encountered problem. Caking is defined by the International Organization for Standardization (ISO) as the formation of a coherent mass from individual particles (ISO, 1984). The coherent mass is held together at the contact points between particles by crystal bridges or other types of bonding. If a material has a tendency to cake, caking can sometimes be reduced by producing larger particles because of a reduced number of contact points. A complex phenomenon, caking is influenced by several factors, which may be interrelated and classified as either internal and external. Internal factors are related to the physical and chemical make-up of the product. Key factors include the moisture content of the product, the size and shape of the particles, the mechanical strength of the product, and its hygroscopic properties. External factors that affect caking include warehouse and storage temperatures, the humidity of the surrounding atmosphere, duration of storage, and the pressure exerted at the bottom of a storage pile (Rutland, 1991a).

The hygroscopic properties or the tendency of a fertilizer to absorb moisture can be expressed quantitatively by the critical relative humidity (CRH) and qualitatively by the moisture absorption-penetration characteristics and flowability during humid exposure. The CRH is a unique property that defines the relative humidity (RH) of the air above which the product begins to absorb a significant amount of moisture from the air. For potash the CRH measured at 30°C is typically between 70–80% (Rutland, 1991a). Variations in the CRH of potash products generally depend on the content and type of impurities on the surface of the granule, commonly sodium and magnesium compounds. Figure 2 indicates the moisture gained or lost by samples of compacted potassium chloride that were exposed to controlled climatic conditions of various relative humidities. Because of the magnesium chloride present on the surface of the granule, sample C begins to absorb moisture below 65% RH of air. The moisture absorption-penetration characteristics or the moisture-holding capacity of a fertilizer material is the amount of moisture that individual particles will absorb before allowing moisture to be transferred to adjacent particles by capillary action. This informa-

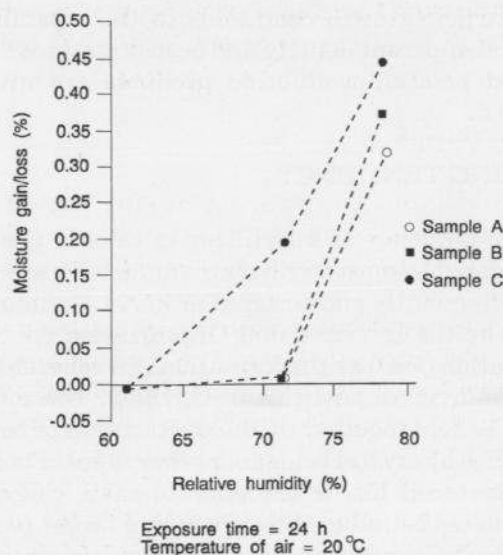


Fig. 2. Graph of relative humidity or air versus moisture gain/loss (%) of compacted potassium chloride products. Source: Kalium Experimental Data.

tion is important in ascertaining storage conditions for bulk piles and in predicting material flowability during handling and application. Flowability during humid exposure gives an indication of the climatic condition at which the fertilizer material maintains its free-flowing state, a state which is always required for efficient handling and distribution. Factors affecting the fertilizer flowability include chemical composition, particle porosity, particle surface area, and degree of crystallinity (Rutland, 1991b). Thus, to fully ascertain the hygroscopic properties of fertilizers the CRH, the absorption-penetration characteristics, and the flowability during humid exposure must be adequately assessed. Methods and procedures are described in the IFDC manual (Rutland, 1986).

Product caking can be further reduced by use of anticaking agents. Usually, cationic fatty amine surfactants are used in the potash industry. These surfactants depress caking mainly because the amine acts as a crystal growth modifier (Gamondes and Van't Hoff, 1977). Surfactants are normally applied in liquid form onto the untreated potassium chloride product either prior to its mine site storage or before the material is loaded into railcars and trucks.

In the potash industry the caking tendency is typically measured by accelerated caking tests. Specifications for equipment and procedures vary between producers. However, most of the procedures operate on the principle that the magnitude of the force required to break a coherent mass (briquette) formed by compression in a mold under controlled conditions is related to the caking tendency. An in-

dication of the relative caking tendency of a product can thus be ascertained with small quantities of product and within a relatively short time. The general equipment and procedures have been described in several publications (Adams and Ross, 1941; Mackay and Sharples, 1985). The basic procedures use a sample of untreated potassium chloride, which serves as a reference, and a conditioned sample. The samples are placed individually in so-called bombs, comprising a cylinder with removable walls and end caps or plungers. Each sample is inserted into a cylinder assembly, and a standard predetermined pressure is applied through an upper plunger, which fits the inside diameter of the cylinder. The pressure is created by regulated air pressure. The whole assembly is placed for a fixed time in a chamber with a controlled climate. The product samples are then removed from the cylinder, and each briquette formed due to caking is broken with a shear-generating assembly. The breaking force required to break the briquette is related empirically to the relative caking tendency of the product. The experiment is carried out several times to obtain an average value. Table 7 shows the magnitude of the force required to break briquettes produced from samples of untreated and treated potassium chloride material. The force required to break the briquette from treated potassium chloride was reduced by a factor of 3 to 9 depending on the type of product tested. Values in Table 7 also indicate the effect that particle size has on caking tendency of fertilizer materials. When the individual particles remain relatively uniform in shape, the caking tendency increases with products of predominantly smaller size, as illustrated with untreated products A, B, and C. Product D is compacted material. Because of its highly irregular shape, product D has a higher irregular surface and more potential contact points, and it tends to cake more than does a sample having a similar size range but more uniform particle shape.

TABLE 7

Relative caking indices for potassium chloride products obtained with accelerated caking procedures and equipment

Product KCl	Force required to break the briquette	
	Untreated (kg)	Treated with anticake (kg)
A. SGN 25	64	9
B. SGN 70	50	9
C. SGN 190	41	5
D. SGN 230 ^a	>68	23

^aCompacted.

Source: Kalium Experimental Data.

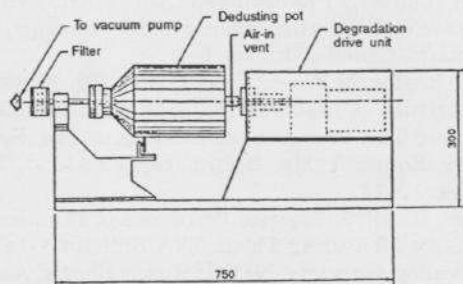
General Specifications

- Dedusting pot**
- 152 mm inside diameter
 - main body 200 mm long, coned @ 45° C/W (3) - 12 mm height flighting
 - 50 mm pipe opening C/W screw cap
 - Overall length 300 mm
 - Weight 3.3 kg
 - Stainless steel construction

Pot revolution @ 33 rpm

Filter ~ .45 μ m

Vacuum pump - initial pressure 15 psi



1. Reagentize the product in a rotary mixer at room temperature. Mix for 10 min.
2. Store the reagentized product for 1 day.
3. Transfer 200 g of product to the dedusting pot along with 50-5/16" steel balls.
4. Weigh the filter apparatus.
5. Attach the filter to the vacuum pump and adjust the vacuum to 15 psi.
6. Rotate for 15 min with vacuum pump running.
7. Weigh the filter apparatus and calculate ppm dust.
8. Wash the pot with methanol after tests with reagentized products.

Fig. 3. Equipment and procedures recommended by SPPA to determine the dustiness index.

Caking procedures and equipment are employed to screen various types of surfactants, to determine their relative effectiveness and addition rates, and to study other important internal and external factors. Results from these tests generally give a good indication of what might be expected in field conditions. However, such correlations are always viewed in the light of considerable practical experience, field observations, and information accumulated in various data bases. Moreover, it is always a sound practice to determine the caking effects over extended time periods in specially designed climate chambers, such as that described in the IFDC manual (Rutland, 1986), to properly test the long-term effect of anti-caking agents before accepting them for mass application.

High-grade potassium chloride products for specific uses are typically marketed free of surfactants or other agents. Caking in this case is countered by limiting storage time between the producer and end user, in which case the material may reasonably maintain its free-flowing characteristics, or by significantly increasing the overall particle size.

Potassium sulfate has a higher CRH, and caking is generally not a problem during product handling

and storage. The CRH of pure potassium sulfate is 97.4% at 30°C as opposed to 83.5% for pure potassium chloride (Arai et al., 1976).

DUSTINESS

In addition to promoting caking, dustiness of potash products may create an environmental and health nuisance at transfer points if the dust particles become airborne. Dustiness can be reduced in potash products by manufacturing harder granules, by screening efficiently, and by product quenching. Dustiness of products may also be reduced by using coating substances, normally viscous oils, which are applied to the granular product together with amines. Product dustiness is reduced because the dust generated through handling adheres to the oil film that envelops the granule. Methods and procedures for measuring dustiness may vary among potash producers. The basic principle and equipment used by most potash producers involve the generation of dust in a tumbler to which a certain number of steel balls are added. The air passing through the tumbler causes a certain size of dust to become airborne and be carried away to a separation device such as a filter or cyclone. The weight of the collected dust gives a dustiness index. Figure 3 outlines the SPPA-recommended dedusting procedures and equipment used on potash products. The procedures and equipment to determine dustiness are also used to monitor the effectiveness of dust suppressants applied to the product. As shown in Table 8, the indices for dustiness of untreated and treated products vary significantly.

TABLE 8

Indices of dustiness for untreated and treated potassium chloride products

Product	Index of dustiness	
	Untreated (ppm)	Treated with antidusting reagent (ppm)
SGN 165	800	300
SGN 230 ^a	1,500-2,000	700-800

^aCompacted.

Source: Kalium Experimental Data.

CONCLUSIONS

Physical and chemical properties define the quality of potash products. These properties serve as direct and indirect tools to monitor, control, and improve the quality of manufactured products. The

physical properties for potash products include PSD, SGN, UI, abrasion resistance, true density, apparent density, porosity, caking tendency, CRH, and dustiness. Various procedures and related equipment are used in determining physical properties. Procedures and equipment used in determining these properties differ among the various potash producers of Saskatchewan and producers of other fertilizer salts. For the last two decades the ISO has attempted to standardize fertilizer physical properties procedures. Thus far, ISO has adopted only six methods as international standards (loose-pour bulk density, tapped bulk density, bulk density of fine-grained fertilizers, angle of repose, sieve analysis, and oil retention in ammonium nitrate). Efforts to standardize methods are currently in progress in Saskatchewan as well and in the long run have the potential to benefit both the consumers and producers. Standardized procedures and equipment, and therefore consistent measurements, would allow consumers to make meaningful comparison of critical storage and handling characteristics of various granular potash products and fertilizer salts in general.

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