1.2%.[2] The titration can be conducted with 0.1 *N* benzoic acid in benzene using thymol blue T.S. eliminating the addition of neutralized alcohol. In this instance, care must be exercised to prevent absorption of atmospheric carbon dioxide during the titration. Analysis of commercial tybamate capsules gave an average value of 97.2 ± 1.2%[2] of the labeled amount of tybamate.

[2] Maximum deviation from the mean value.

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# *Technical Articles*

# Particle Size Distribution and Hopper Flow Rates

By EDWARD D. SUMNER*, HERMAN O. THOMPSON, WILLIAM K. POOLE, and JAMES E. GRIZZLE

**The rate of flow of varying ratios of four sieve size fractions of rock salt through the hopper of a rotary press was represented by a second degree polynomial equation. This fitted polynomial accounted for 90 per cent of the variation in the mean flow rates. No correlation was found between the tangent of the angle of repose and flow rate. High positive correlation was found between flow rate and bulk density, while high negative correlation between flow rate and porosity was observed. There was no significant increase or decrease in flow rates with regard to the quantity of rock salt remaining in the hopper.**

One of the most important considerations in pharmaceutical manufacturing is the flow of particulate solids through hoppers and feeders. Capsules, divided powders, and tablets are examples of solid dosage forms which require measured filling for the production of each unit. Thus, the uniformity of the final product requires a uniform flow rate of these solid mixtures. Modern tablet machines are capable of compressing from 5000 (1) to 22,000 (2) tablets per minute. Uniformity of flow rate and flow rate of particulate solids must be considered in order to meet the requirements of these high speed units.

The laws which govern static pressures of fluids do not apply to particulate masses. Some properties of liquids in containers are: pressure is identical throughout at the same depth, pressure exerted on any point is transmitted undiminished to every portion of the enclosed liquid, and pressure exerted by a liquid on the walls of the container is always at right angles to the surface of the container.

Unlike liquids, pressures of bulk solids contained in hoppers varies with direction at different points, pressure is dependent on the shape and size of the receptacle, and the weight of a solid is transferred to the walls by shearing between particles in addition to pressure.

The principal factors affecting flow rates of particulate solids are: particle size, particle size distribution, particle shape, density, surface characteristics, and relative size and geometry of the hopper (3).

A review of the literature (3–15) reveals that the majority of the investigations and research on flow of particulate solids have been conducted on monodisperse systems and hoppers of much larger or smaller dimensions than those ordinarily used in some pharmaceutical manufacturing processes. This work was conducted to ascertain what relationship existed between particle size distribution, bulk density, porosity, and tangent of angle of repose in regard to flow rates and uniformity of flow rates.

## MATERIALS AND METHODS

**Material.**—The particulate solid used was rock salt in the following sieve size fractions: 8/10, 10/20, 20/40, 40/60.

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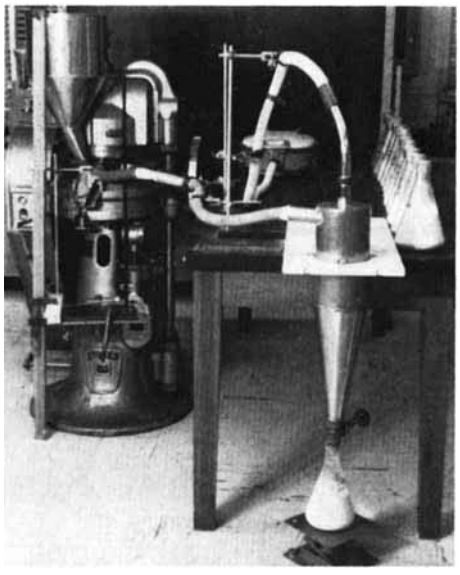

Fig. 1.—Pictorial view of flow apparatus.

**Preliminary Investigation.**—Since the distance between the hopper orifice and die table of the Stokes rotary press, model D-3, has some regulatory effect on flow rates of particulate solids, the position of the hopper must be stabilized in order to eliminate sagging when the hopper is charged. Preliminary studies revealed that if the hopper height was not controlled, the flow rates gradually increased as the hopper empties due to an increase in the hopper orifice–die table height. Classification studies of rock salt flowing from the rotary press hopper could not be carried out because of fracturing and attrition in the feed frame and cyclone separator.

**Flow Rate.**—An over-all view of the experimental layout for measuring the rate of flow is shown in Fig. 1. The rotary press, model D-3, was run at a speed of 13.3 r.p.m. throughout the study. The upper punches were left out and the lower punches were adjusted to a depth of 2 cm. The height of the hopper orifice was set at a distance of 0.7 cm. from the die plate.

The hopper supplied with the machine was charged with 22 Kg. of rock salt for each run. The main vacuum nozzle and the auxiliary nozzle were placed in such a position to make collections of all material falling on the die plate as well as material filling the dies. The vacuum for the cyclone separator was furnished by a vacuum cleaner equipped with 1.5-hp. motor.

After placing a 2000-ml. conical flask in position under the cyclone separator, the vacuum system and machine were started. The initial 1-min. collection was discarded and not used in the data. This was done in order to allow the machine and flow to become stabilized.

At 1 min., the shut-off valve on the separator was closed, the flask removed, an empty flask was again placed beneath the separator, and the shut-off valve was opened. The samples were numbered 1, 2, etc., in the order collected. This procedure was continued until the hopper was nearly empty or as long as 1-min. collections could be removed. The rock salt was used over again after subjecting it to sieving to remove fractured material.

**Bulk Density.**—The bulk density was determined by the procedure set forth by Butler and Ramsey (16). The reported value is an average of three determinations.

**Porosity.**—Porosity was calculated from the following formula (17):

$$\%e = V_b - V_p/V_b \times 100$$

where $V_b$ and $V_p$ represent the bulk and true volumes, respectively.

**Moisture Determination.**—All moisture determinations were made on the Ohaus moisture balance, model 6000. The heater was set at a distance of 1.25 in. from the pan, and the samples were dried for a period of 1 hr. One sample was taken initially and the second was taken after total discharge of rock salt from the hopper. The percentage of moisture never exceeded 0.3%, and the initial and final samples seldom varied.

**Angle of Repose Measurements.**—Instrumentation for measuring the angle of repose is shown in Fig. 2. The glass cylinder was charged with 1000 Gm. of the respective rock salt combination. The funnel on top of the cylinder permitted uniform loading from batch to batch. The plug in the center of the base was removed, and the material flowed out of the orifice. The height of the cone remaining on the platform was measured to the nearest ±0.05 cm. A total of three determinations was made and the reported value is an average of these. The tangent, $\phi$, was calculated from the formula (18): tangent $\phi$ = H/R, where H is the height of the cone, and R is the radius of the platform.

***Determination of Hydrostatic Pressures.***—Although some relationships have been determined between height of particulate solids and unit pressure in hoppers (5), it seemed desirable to conduct some work utilizing the rotary press hopper.

The rotary press hopper was leveled and clamped in such a manner that the orifice rested on the table

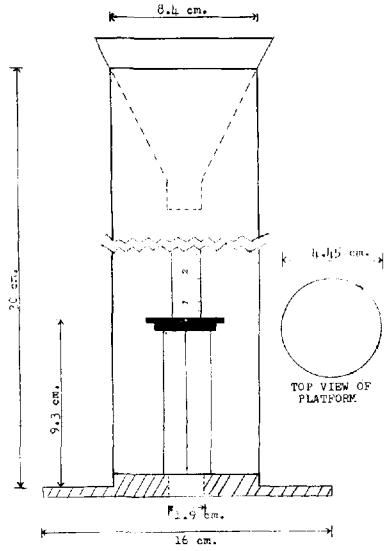


Fig. 2.—Instrumentation for determining angle of repose.

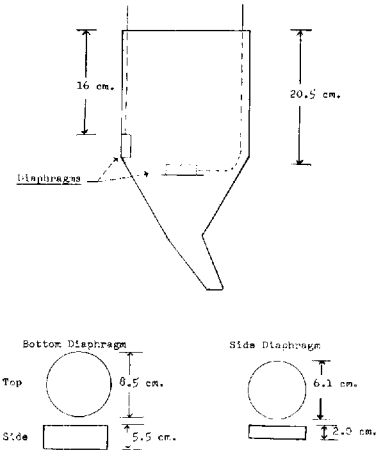


Fig. 3.—Apparatus for determining hydrostatic pressures.

surface. At first, the hopper was partially filled with rock salt. This was done to determine pressures in the larger section of the hopper.

The diaphragms were made from cylindrical metal containers which were covered on the top surface with a sheet of thin rubber. A combination of copper and glass tubing was used for retaining the water from the diaphragms. The diaphragms and tubing were filled to an arbitrary point.

The bottom diaphragm rested on a metal plate above the stationary level of material. The positions of the diaphragms are shown in Fig. 3. Fifteen kilograms of the respective rock salt combination was loaded into the hopper and lightly leveled on the surface. Under pressure of the loaded material, the rubber covering was compressed which resulted in an increase of the water level in the tubing. The water levels of the vertical and lateral diaphragms were measured from the initial markings within 1 min. after the hopper was charged. The experiment was carried out at 27 ±1°.

## STATISTICAL ASPECTS OF THE INVESTIGATION

**Design of the Experiment.**—If the assumption is made that conditions in the machine such as speed, particle size distribution of a given mixture, hopper height, etc., remain constant throughout the entire experimentation, it is reasonable to assume that the response (rate) may be represented by some mathematical function of the constituents being used. This gives rise to what is commonly called a response surface. In this experiment, it was decided that a second degree equation should be tried, and then unneeded terms of this equation could be eliminated. The proposed model (*A*) is shown below.

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{3} \beta_{ij} X_i X_j + E \quad \text{(Model } A\text{)}$$

where

$Y$ = flow rate for a given set of $X$'s (*i.e*, a given mixture),
$\beta$ = regression coefficients (unknown),
$X_i$ = proportions of each sieve size rock salt,
$E$ = random uncontrollable error.

The substance at any filling may be represented by

$$X_1 + X_2 + X_3 + X_4 = 1$$

where $X_1$ = % of 8/10, $X_2$ = % of 10/20, $X_3$ = % of 20/40, $X_4$ = % of 40/60. Percentages are expressed in decimals.

Much work has been done in setting up designs in response surfaces, and in these works optimum properties are achieved by properly placing the design points (*i.e.*, $X_1$, $X_2$, $X_3$, $X_4$). However, no one seems to have considered the case where the independent variables are restricted by inequalities as in this experiment. This being the case, it was felt that the best that could be done would be to choose a design which (*a*) permits estimation of all regression coefficients of the equation ($\beta$'s) and (*b*) permits analysis of the variability in response at different combinations of the $X_i$'s.

The design of the experiment chosen was one in which (*a*) each sieve size was run separately, (*b*) sieve sizes were run in pairs, (*c*) sieve sizes were run in triplets, and (*d*) all sieve sizes were run at the same time. These various combinations are shown in Table I. Note that some of the mixtures were run twice, (*i.e.*, *7* and *24* are the same, *15* and *25*, etc.).

## RESULTS AND DISCUSSION

A summary of the average flow rates and standard errors, tangent of the angle of repose, bulk density,

TABLE I.—COMBINATIONS OF ROCK SALT USED FOR FLOW STUDIES

| Combination | Proportions $X_1$ 8/10 | $X_2$ 10/20 | $X_3$ 20/40 | $X_4$ 40/60 |
|---|---|---|---|---|
| *1* | 1.000 | ... | ... | ... |
| *2* | ... | 1.000 | ... | ... |
| *3* | ... | ... | 1.000 | ... |
| *4* | ... | ... | ... | 1.000 |
| *5* | 0.500 | 0.500 | ... | ... |
| *6* | 0.500 | ... | 0.500 | ... |
| *7* | 0.500 | ... | ... | 0.500 |
| *8* | ... | 0.500 | 0.500 | ... |
| *9* | ... | 0.500 | ... | 0.500 |
| *10* | ... | ... | 0.500 | 0.500 |
| *11* | 0.333 | 0.333 | 0.333 | ... |
| *12* | 0.333 | 0.333 | ... | 0.333 |
| *13* | 0.333 | ... | 0.333 | 0.333 |
| *14* | ... | 0.333 | 0.333 | 0.333 |
| *15* | 0.250 | 0.250 | 0.250 | 0.250 |
| *16* | 0.718 | 0.094 | 0.094 | 0.094 |
| *17* | 0.094 | 0.718 | 0.094 | 0.094 |
| *18* | 0.094 | 0.094 | 0.718 | 0.094 |
| *19* | 0.094 | 0.094 | 0.094 | 0.718 |
| *20*[a] | 0.100 | ... | ... | 0.900 |
| *21*[a] | 0.179 | ... | ... | 0.821 |
| *22*[a] | 0.250 | ... | ... | 0.750 |
| *23*[a] | 0.400 | ... | ... | 0.600 |
| *24*[a] | 0.500 | ... | ... | 0.500 |
| *25*[a] | 0.250 | 0.250 | 0.250 | 0.250 |
| *26*[a] | 0.333 | ... | 0.333 | 0.333 |

[a] Indicates that these combinations were run after the experimental data were processed for the first 19 combinations.

TABLE II.—SUMMARY OF DATA OBTAINED FOR MEAN FLOW RATE, TANGENT ANGLE OF REPOSE, BULK DENSITY, POROSITY, AND S.D. OF MEAN FLOW RATE

| Combination | Av. Flow Rate, Gm./min. | Tangent Angle of Repose | Bulk Density, Gm./ml. | Porosity, % | S.E.,[a] Gm./min. |
|---|---|---|---|---|---|
| *1* | 1167.843 | 0.7870 | 1.10 | 49.00 | 13.8786 |
| *2* | 1675.500 | 0.7110 | 1.17 | 46.00 | 3.6703 |
| *3* | 1768.958 | 0.7100 | 1.16 | 46.20 | 8.9768 |
| *4* | 1903.550 | 1.1310 | 1.14 | 47.25 | 6.1750 |
| *5* | 1542.428 | 0.7940 | 1.17 | 46.00 | 8.4208 |
| *6* | 1832.136 | 0.8170 | 1.24 | 42.80 | 4.8683 |
| *7* | 2064.666 | 0.9137 | 1.31 | 39.38 | 11.4560 |
| *8* | 1788.458 | 0.7492 | 1.21 | 44.12 | 7.9189 |
| *9* | 1955.550 | 0.8616 | 1.28 | 40.53 | 4.7476 |
| *10* | 1883.850 | 0.8166 | 1.21 | 44.02 | 10.4109 |
| *11* | 1844.750 | 0.8616 | 1.23 | 43.19 | 6.4506 |
| *12* | 1908.450 | 0.8912 | 1.25 | 42.08 | 8.1443 |
| *13* | 1969.850 | 0.7640 | 1.29 | 40.01 | 2.1633 |
| *14* | 1937.722 | 0.7043 | 1.27 | 41.03 | 8.3917 |
| *15* | 1981.950 | 0.7865 | 1.29 | 40.25 | 4.5640 |
| *16* | 1827.333 | 0.9213 | 1.24 | 42.61 | 6.4707 |
| *17* | 1794.850 | 0.8840 | 1.21 | 43.89 | 2.7821 |
| *18* | 1861.150 | 0.7115 | 1.24 | 42.80 | 3.4569 |
| *19* | 1952.277 | 0.8013 | 1.27 | 41.36 | 3.6083 |
| *20* | 1890.600 | 1.0920 | 1.20 | 44.34 | 6.3443 |
| *21* | 1942.400 | 0.8220 | 1.25 | 42.00 | 3.7881 |
| *22* | 1944.800 | 0.7560 | 1.30 | 40.00 | 4.9649 |
| *23* | 1991.833 | 0.7560 | 1.32 | 39.10 | 9.0576 |
| *24* | 2054.389 | 0.7640 | 1.32 | 38.75 | 6.9340 |
| *25* | 1960.150 | 0.7870 | 1.28 | 40.60 | 5.7280 |
| *26* | 1957.600 | 0.7330 | 1.29 | 40.10 | 7.6883 |

[a] Standard deviation of mean flow rate.

and porosity is shown in Table II. Table III shows the results of the hydrostatic pressure measurements.

**Statistical Analysis.**—In the discussion, the following conventions have been adopted: *observation*, a single determination for a specific combination; *sample*, the aggregate of observations for a specific combination; *experiment*, the totality of samples for all combinations. After running the first 19 combinations shown in Table I, plots of each sample were made on a time scale and on separate pieces of graph paper. The main purpose of this was to determine if any trend existed in flow rate from the first observation taken in each sample to the last. It is noted that the model proposed assumes no such trend (*i.e.*, it assumes each observation in a sample to be about like any other observation, apart from random error). The plots suggested that in some instances there appeared to be trends. Statistical tests showed, however, that the "apparent trends" could be attributed to chance variation in the data, and thus, model $A$ was considered adequate.

As a by-product of this investigation mentioned above, a preliminary fit[1] of a modified form of the proposed model was obtained. This modified model is shown as model $B$.

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + E \quad \text{(Model } B\text{)}$$

This fitted equation provided an estimate (perhaps rough) of the design point which would produce the greatest flow rate. This was:

[1] The term "fit" refers to the estimation of the unknown $\beta$'s from the data. The least squares technique was used in estimating these coefficients.

TABLE III.—HYDROSTATIC PRESSURES OF ROCK SALT IN ROTARY PRESS HOPPER

| Sieve Size | Pressure in cm. Water[a] Vertical | Lateral | Increase of Lateral Above 8/10 Fraction, % |
|---|---|---|---|
| 8/10 | 6.35 | 1.45 | ... |
| 40/60 | 8.65 | 1.85 | 27.6 |
| 8/10 40/60[b] | 6.60 | 2.03 | 40.0 |

[a] Glass tubing with inside diameter of 0.3 cm. [b] 50% of each mixed together.

$$\hat{X}_1 = 0.1794 \ (\%\ 8/10 \text{ fraction})$$
$$\hat{X}_2 = 0.0000 \ (\%\ 10/20 \text{ fraction})$$
$$\hat{X}_3 = 0.0000 \ (\%\ 20/40 \text{ fraction})$$
$$\hat{X}_4 = 0.8206 \ (\%\ 40/60 \text{ fraction})$$

It is noted that the design point tested producing the maximum flow rate in the experiment was

$$X_1 = 0.5000 \ (\%\ 8/10 \text{ fraction})$$
$$X_2 = 0.0000 \ (\%\ 10/20 \text{ fraction})$$
$$X_3 = 0.0000 \ (\%\ 20/40 \text{ fraction})$$
$$X_4 = 0.5000 \ (\%\ 40/60 \text{ fraction})$$

At this point in the investigation it seemed advisable to take a few more samples in order to get a good fit of model $A$ in the region of the suspected maximum flow rate (*i.e.*, the predicted maximum) and so that differences in flow rate and variation could be examined for repeated sampling of the same mixture. Since no trend existed with regard to the time an observation was taken, the means of the flow rates were thought to be indicative of the performance of a particular combination. Also, in using the means of the flow rates a source of varia-

tion was eliminated in fitting the model (*i.e.*, within combination variation).

With this in mind, model $A$ was fitted to the means arising from samples *1* through *26*. Tests were carried out to determine whether any of the regression coefficients could be eliminated, and the results indicated that $\beta_3$ and $\beta_{33}$ could be considered as zero. If these coefficients are set equal to zero in model $A$, the resulting model may be called model $A'$.

Model $A'$ then is the one that should be used for this experiment. The data were fitted to model $A'$ (*i.e.*, model $A$ with $\beta_3 = \beta_{33} = 0$), and the resulting fitted equation along with the standard deviation of the estimated parameters (in parentheses) are given below.

$$\hat{Y} = \hat{\beta}_0 + \sum_{i=1}^{2} \hat{\beta}_i X_i + \sum_{i=1}^{2} \hat{\beta}_{ii} X_i^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{3} \hat{\beta}_{ij} X_i X_j$$

$$\begin{aligned}
\hat{\beta}_0 &= 1812.7531 \quad (32.3132) \\
\hat{\beta}_1 &= 1311.3557 \quad (187.9531) \\
\hat{\beta}_2 &= 778.7229 \quad (248.3857) \\
\hat{\beta}_{11} &= -1878.3369 \quad (194.3749) \\
\hat{\beta}_{22} &= -935.3288 \quad (257.8770) \\
\hat{\beta}_{12} &= -2261.2628 \quad (408.3098) \\
\hat{\beta}_{13} &= -510.4626 \quad (262.2961) \\
\hat{\beta}_{23} &= -589.9348 \quad (340.8922)
\end{aligned}$$

The estimates of the $X_i$'s from the above equation which would produce the maximum flow rate were calculated to be:

$$\begin{aligned}
\hat{X}_1 &= 0.3491 \ (\%\ 8/10 \text{ fraction}) \\
\hat{X}_2 &= 0.0000 \ (\%\ 10/20 \text{ fraction}) \\
\hat{X}_3 &= 0.0000 \ (\%\ 20/40 \text{ fraction}) \\
\hat{X}_4 &= 0.6509 \ (\%\ 40/60 \text{ fraction})
\end{aligned}$$

Since model $A'$ has fewer parameters than model $A$, it is natural to inquire as to what is lost, if anything, by choosing the simpler model. This question is generally answered by using the multiple correlation coefficient, $M$, associated with each fitted model. The square of $M$ is actually the percentage of the total variation in the sample means which is accounted for by the fitted model. The $M$ corresponding to the fitting of $A$ was found to be 0.9552, while that for $A'$ was 0.9501; hence, the fitted $A'$ is just about as good a predictor of flow rate as is the fitted $A$. In fact, it was found that if all regression coefficients with a three in the subscript were set equal to zero (*i.e.*, $\beta_3 = \beta_{33} = \beta_{13} = \beta_{23} = 0$), then the fitted model had an $M$ of 0.9270. This means that knowledge of $X_3$ helps very little in predicting mean flow rates. In other words, the absence or presence of the $^{21}/_{40}$ fraction in the mixture has little effect on the mean of the flow rates.

**Linear Correlation of Flow Rates with Angle of Repose, Bulk Density, and Porosity.**—The sample correlation coefficient between flow rate and various other measurements is defined as

$$r = \frac{\sum_{i=1}^{n} (X_i - \bar{X})(Y_i - \bar{Y})}{\left[\sum_{i=1}^{n} (X_i - \bar{X})^2 \cdot \sum_{i=1}^{n} (Y_i - \bar{Y})^2\right]^{1/2}}$$

where $X_1, X_2, \ldots, X_n$ are the mean flow rates of the 26 samples and $Y_1, Y_2, \ldots, Y_n$ are the values corresponding to the variable whose linear correlation with flow rate is to be investigated.

**Tangent of Angle of Repose.**—$r_1 = +0.1022$. A statistical test showed that the true correlation could be considered zero, and the conclusion was made that the tangent angle of repose is uncorrelated with flow rate.

**Bulk Density.**—$r_2 = +0.8123$. This suggests a positive correlation and hence the conclusion was made that flow rate is positively correlated with bulk density.

**Porosity.**—$r_3 = -0.8160$. This indicates a negative correlation with flow rate.

**Variation of Flow Rates.**—The usual standard deviation of the mean was computed for each combination and used as a measure of variation of flow rate (see Table II). A statistical comparison revealed that not only are there significant differences in the variation for different mixtures (*i.e.*, combinations *1* and *13*), but there are also significant differences in the variation of flow rate of the same mixture run two different times (*i.e.*, combinations *13* and *26*). The differences in the first case were not so surprising as those in the second case due to changing bulk density, porosity, and particle size in the former. No explanation can be offered at this time as to why combinations *1*, *7*, and *10* had the greatest standard deviation. The variation of the standard error in the second case (*i.e.*, combination *13* and *26*) was probably due primarily to differences in the particle size distribution at different times. This, however, was not verified.

## SUMMARY

Flow rates were obtained from constantly flowing material which approached tableting operations. There was a maximum point at which the further addition of 40/60 fraction of rock salt to the 8/10 fraction decreased the flow rate. This maximum point, among those tested, was when 50% each were mixed. The fitted model places the maximum at 35% of the 8/10 fraction and 65% of the 40/60 fraction. No correlation was found to exist between the angle of repose and flow rate.

Other factors had an effect on the flow rate. Bulk density increased with a decrease in porosity when different particle size systems were mixed. Hence, flow rate was increased due to more weight per unit volume being delivered from the hopper orifice. The flow rate was increased by the addition of smaller particles to larger particles which appeared to act as a lubricant when the voids were partially filled. Lateral hydrostatic pressure measurements on 8/10, 40/60, and 50% of 8/10 and 40/60 fractions of rock salt showed that the flow rate increased with increasing pressures, though the same relationship with vertical hydrostatic pressure does not seem to exist.

The standard error varied from a low of 2.1633 to a high of 13.8786 for various combinations of rock salt. There is an apparent difference in the uniformity of flow rate from one combination to another. However, no obvious simple trend exists since the highest variability was associated with the lowest flow rate, while the second highest variability was associated with the highest flow rate.

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# Notes

## Direct Titrimetric Determination of Aromatic Quaternary Ammonium Salts and Long Chain Aliphatic Sulfates and Sulfonates

By JOYE A. BILLOW and H. WELDON BAKER

**Aromatic quaternary ammonium salts and long chain aliphatic sulfates and sulfonates can be assayed by a rapid, single phase aqueous titration. Sodium tetraphenylboron serves as a direct standard in the assay of the quaternaries and benzalkonium chloride as the titrant for anionic detergents. Bromophenol blue indicator gives a purple to blue color change when the anionic substances are titrated in strongly alkaline solution. The results of this method show excellent agreement with the standard chloroform extraction titration.**

THE aromatic quaternary ammonium salts official in U.S.P. XVII and N.F. XII are assayed by many different methods. Sodium lauryl sulfate, the only official long chain aliphatic sulfate, is not directly assayed. It was believed that a single method type, direct titration of large anions with large cations, could be used for all aromatic quaternary ammonium salts and for the long chain aliphatic sulfates and sulfonates.

A direct titration of sodium tetraphenylboron with cetyltrimethylammonium bromide using bromophenol blue indicator was used by Schall (1) in the determination of potassium. This suggested that aromatic quaternary ammonium compounds could be assayed by direct titration of sodium tetraphenylboron, and, conversely, that large anions could be titrated directly with quaternary ammonium compounds.

Cetylpyridinium chloride is officially assayed (2) by titration with standard sodium tetraphenylboron using bromophenol blue indicator. The official method differs from that proposed by Schall in that the end point depends upon the extraction of the indicator from a chloroform layer.

A similar chloroform extraction titration, using tetrabutylammonium iodide as the standard, is official (3) for the assay of the aliphatic sulfonate dioctyl sodium sulfosuccinate. This method is adapted in method *A* as the general chloroform extraction method against which the proposed method is compared.

### REAGENTS

**Tetrabutylammonium Iodide (Primary Standard Cation).**—A 0.01000 *M* solution prepared considering the material to be 100% pure. Titration in triplicate against sodium tetraphenylboron by method *A* gave 0.01000 *M* ± 0.00005 *M*.

**Sodium Tetraphenylboron (Primary Standard Anion).**—A 0.01000 *M* solution prepared on the basis of labeled 99.6% assay. This should be freshly prepared before each use because of decomposition on standing in solution.

**Benzalkonium Chloride (Secondary Standard Cation).**—Approximately 0.01 *M* solution prepared by diluting about 30 ml. of 12.8% benzalkonium chloride[1] to 1 L. and standardized against sodium tetraphenylboron by N.F. XII procedure for cetylpyridinium chloride (2).

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[1] Marketed as Zephirin Chloride by Winthrop Laboratories, New York, N. Y.