PROCEEDINGS

OF THE

FERTILIZER INDUSTRY ROUND TABLE

1958

Held at the
MAYFLOWER HOTEL
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November 5, 6 and 7, 1958

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Executive Committee

Vincent Sauchelli, Chairman
H. L. Marshall
J. E. Reynolds, Jr.
Albert Spillman

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V. Sauchelli, National Plant Food Institute,
1700 K Street, N. W., Washington 6, D. C.

H. L. Marshall, 1604 Walterswood Road,
Baltimore 12, Maryland

Opening Remarks

Vincent Sauchelli, President

WELCOME to the 1958 Fertilizer Industry Round Table. In this group is the nation's finest talent in fertilizer knowledge and technology. It is indeed a privilege and a pleasure to greet this splendid assembly.

The program this year is built around the theme, *"Economics"* and is divided into three parts: Economics of Preventive Maintenance; Economics of Processing; and Economics of Formulation. Remember, I and your Executive Committee try our best in organizing these programs to carry out your suggestions. This year we continued the procedure used so successfully last year: that is, a question and answer program. That reflects the spirit of our Round Table. These meetings provide a forum where operational personnel of the industry have the opportunity to discuss informally problems of mutual interest. This is your meeting because the questions to be ably discussed are your questions and the answers will be given by your own colleagues. May it always be that way!

We have a slight innovation this year in our procedure. To introduce the theme of each main division we have selected a competent authority to sort of set the stage for the theme. We hope the plan works out as well as expected.

Last year we undertook to edit and publish our proceedings independently. The job was a major undertaking. We got a liberal education in the high cost of printing. It looked for a while as though we might not be able to go through with it owing to a shortage of funds. Your Executive Committee appealed to the membership for aid in getting orders for enough additional copies to pay the cost of printing. The response was very generous. We made our budget and had a small carryover in the kitty. We are planning to print this year's Proceedings on our own again and trust to the interest of our membership and their employer companies to purchase sufficient copies to meet our expenses. The information in the Proceedings is worth many, many times more than the cost. Last year we absorbed the mailing charges; this year they will be included in the selling price. This seemed preferable to increasing the registration fee.

We regretted the necessity that caused us to change the date and hotel originally designated. Numerous conflicts with other important agricultural meetings was responsible. We were fortunate in being able to switch the meetings to this fine hotel. Perhaps we may decide to return here in 1959.

May I take this opportunity to thank my Committee colleagues and the members who cooperated by sending us questions and suggestions for their good will and work. Remember we get no compensation for our labors, except the satisfaction of doing something worthwhile for the good of the industry. We naturally like to hear appreciations from our colleagues. The National Plant Food Institute is very generous in allowing me to put considerable time in this work of the Round Table and also in providing stenographic help and other services. I am pleased to acknowledge with much appreciation their unstinted cooperation.

The 1958 Round Table will now get down to business!

You have the list of questions that will be discussed today. The theme is: Economics of Preventive Maintenance.

To set the stage for today's sessions, we were able to get a man of unexcelled competence, a graduate of Drexel Institute of Technology, who then worked his way in industry starting as welder's helper, maintenance helper, and machine operator to become a full-fledged design and installation engineer in the U. S. Navy and consultant to a maintenance consulting group. He has held numerous responsible positions in engineering and has also found time to teach. He is now employed by the du Pont Engineering Department at Wilmington, Delaware. as Group Supervisor to the Maintenance Engineering Section of that organization.

Gentlemen, it gives me great pleasure to present Mr. Jesse C. Jessen. The subject of his talk is: Reducing Maintenance Costs.

Wednesday, November 5

Reducing Maintenance Costs

J. C. Jessen

If you were able to project yourself backward for a million years, you would see man fighting for his existence using only his five senses, his brain, and his arms and legs. As the need for a weapon arose, he would pick up a fallen branch or stone to provide an extension to his arms and hands. After use, these would be discarded and others obtained as new emergencies arose. However, about 500,000 years ago, his descendants began to realize that these offensive and defensive aids were not always available and that it was wise to carry them in case of sudden need. At the University of Witswatersrand in Johannesburg, you can find fossils of typical tools such as an antelope mandible for cutting, a hyena lower jaw for slashing, and a wild pig tusk for ripping. Some of these tools have been battered by use. As soon as our prehistoric forebearer valued his tool enough to dress up the weapon to make it more useable, he became involved with the maintenance activity. We have been engaged in this activity ever since, making it one of our oldest professions.

Progressing to a period of approximately 50,000 years ago, we find evidence of the use of spears and bows and arrows as well as axes, with pieces of stone or bone tied to a spear or club. This simple fastening method became our first critical maintenance problem. Up to this point the word "tools" has included only weapons. Starting approximately 6,500 years ago, during the Bronze Age, we begin to find the use of tools for both primary and secondary work; that is, secondary tools such as this elementary bow drill and saw were used for the manufacture of primary tools such as plows and sickles for direct agriculture purposes. About this time, measuring devices also came into use with standard measurements such as the "digit" meaning width of thumb, "palm" and "cubit" meaning measurement from elbow to finger tips. Our maintenance problem, as you can see, is growing.

The Industrial Revolution began about 150 years ago. This was our first major advance through part standardization and use of mechanical power to replace manual effort and horsepower. Equipment such as the Whitney cotton gin, the Fulton steamboat, and steam locomotive began to make their appearance. All of these "primary" tools had the effect of reducing the energy of man and animals but increasing the need for "secondary" or maintenance tools to maintain the even more complex equipment. Starting in 1850, we can see the overall effect of the use of production equipment in the U. S. to increase the production of goods and services for the consumers. In 1850, men supplied 23% of energy used in industry and the output per man hour was only 27¢ worth. By 1950, men supplied only 4% of total energy and the value of goods and services reached $1.21. Note how the total tool investment and number of employees have both continued to increase, which tends to nullify the statement of many labor leaders that "Automation is taking food from hungry mouths." The result of the greatly increased productivity is that more goods are available to more people at a lower cost.

What does all this indicate? Technology is replacing manpower in production wherever possible by mechanical power and equipment. What we do not always appreciate is that the 33 billion dollars worth of tools and equipment in this country begins to wear out the instant it is put into use.

What of du Pont? Have we followed the overall trend? Figure 3 shows du Pont curves since 1940. Since 1945, the wage roll, other than maintenance, has been maintained almost constant, although du Pont has doubled its productivity in pounds since that time. The maintenance wage roll, however, has increased 60% during that period. On four plants we now have more maintenance than operating, wage roll people. These mechanics are involved in the maintenance of complex plants, where the process equipment is integrated into continuous systems. With the older, batch type plants our mechanics can maintain one kettle or pump or vessel without seriously disturbing overall plant output. But when this equipment is tied together by conveyors or by piping systems, we have an inte-

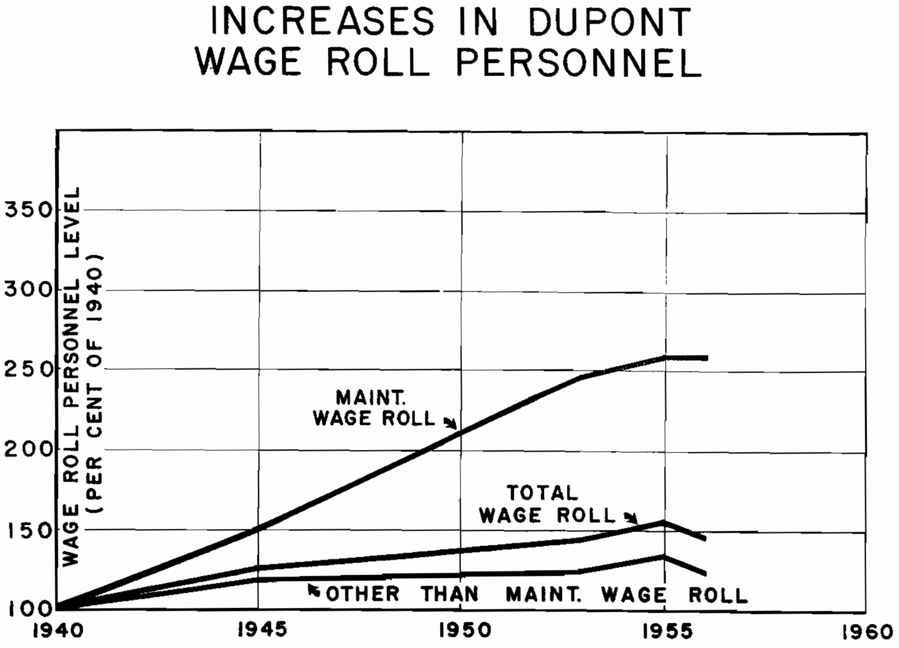


Figure 3

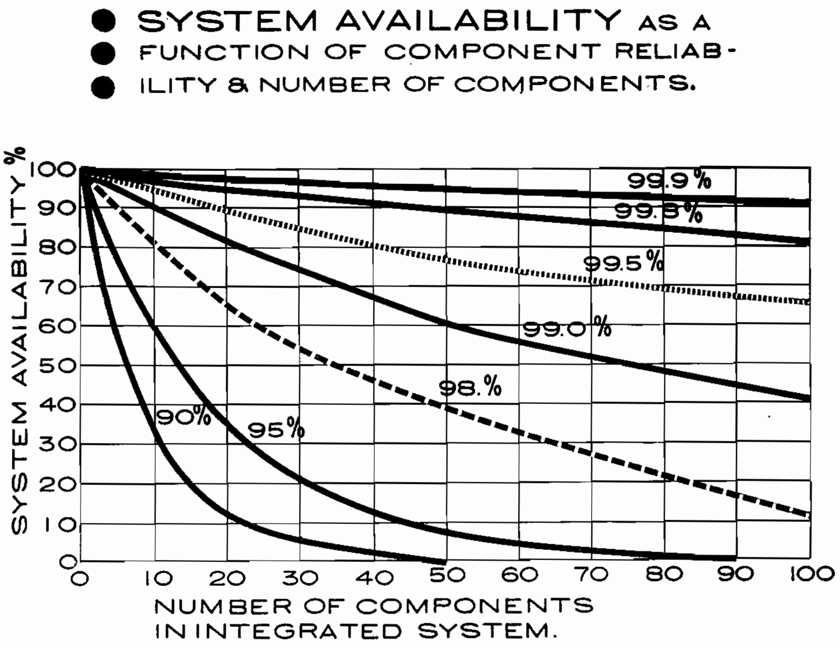
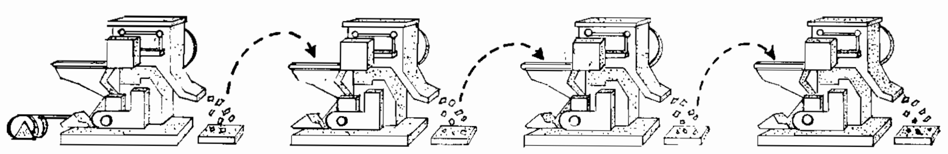


Figure 1

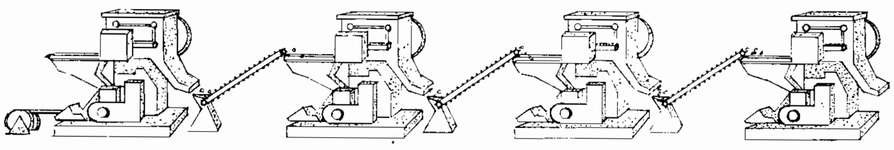
grated plant in which a whole system goes down when a single component fails. This means that we might have 5, 10, 20 or more machines performing consecutive operations on one continuous line *that all stop when one stops* rather than having, say 20 separate machines of which *19 continue to produce* while one stops. Let me make it clear that we believe in automation. Without it, we could not compete; but let us look at this interesting arithmetic. Fig. 1 shows a family of curves calculated on a purely statistical basis. If we have 50 separate pieces of equipment in a plant in series, each with an availability of 99.9%, our total plant availability would be *99.9%* as work in process inventory could be used to keep the other machines going, even if one was down for repair. If these are all tied together in one automated line-on the basis of mathematical probability, the plant availability is 95%. The next Figure 2 shows four succeeding operations on a theoretical production line. In this case, a unit availability of 90% was assumed. Using the 90% curve from the previous figure, if any one piece of equipment failed, the other three pieces of equipment could continue to operate from work-in-process inventory and the availability of the whole line would be 90% because the random failure of equipment would not normally interfere with the production of the other pieces. If we would, however, put transfer mechanisms or conveyors between the four pieces of equipment as shown on the lower half of the slide, the failure of any one piece of equipment would shut down the whole line. Using the 90% curve on the previous figure, this makes the line availability only 55%. To extrapolate still further using the same curve of 90% availability, connecting 50 pieces of equipment in series would make the plant inoperable if the shutdown is not planned to perform critical maintenance on all components simultaneously. Is it any wonder then, that we say responsibility is passing from the production organization to the maintenance organization. The Works Engineer must concern himself with the total mill cost of the produce. It is not as important to know whether maintenance cost is going up or down as it is to know that mill cost is being lowered and high quality production maintained. On the next Figure 3 we see that the total du Pont wage roll personnel has been increased to 150% of the 1940 base. If we extract from this curve the *total maintenance employees*, we find that the so-called "all others" curve has increased to 125% of the 1940 base. Now, let's look at the maintenance labor curve for the same period and we will find an increase in the maintenance labor wage roll force to 250%. Our maintenance labor roll in the du Pont Company is increasing *six times as fast as all other wage roll.*

SUCCEEDING OPERATIONS ON PRODUCTION LINE



BEFORE CONVEYORIZATION

UNIT AVAILABILITY = 90% – LINE AVAILABILITY = 90%



AFTER CONVEYORIZATION

UNIT AVAILABILITY = 90% – LINE AVAILABILITY = 55%

Figure 2

What have we done to handle this maintenance problem most effectively? What type of controls do we use? How is it organized? Finally, would these controls be useful to you despite probably differences in product, plant size, type of industry and organization?

I think so! To illustrate—

The du Pont Company has 79 plants of various sizes located in 65 communities in 26 states. These vary greatly in size and number of employees, some from less than 100 to more than 2,000 employees with an average number slightly less than 1,000.

The tremendous diversity of plant size, plant age, product, etc., prohibits the establishment of any one standard du Pont system of controls. What has been established is a system of 18 basic tools tailored to conform to each plant organization, accounting procedures, tabulating equipment, product, plant size and policy wishes of the plant manager.

They are as follows:

1. Set Up a Proper Maintenance Organization
2. Establish A Work Order System
3. Keep Equipment Records
4. Analyze and Plan Jobs
5. Make Weekly Forecasts
6. Prepare Daily Schedules
7. Set Up Manpower Backlog Control
8. Establish A Preventive Maintenance Program
9. Use Budgetary Control
10. Provide Material Control
11. Plan Your Plant Shutdowns
12. Set Up Major Overhaul Procedures
13. Develop Standard Practices
14. Use Work Measurement
15. Improve Your Equipment
16. Train Your Supervisors
17. Train Your Maintenance Men
18. Analyze Performance and Costs

These basic tools are listed in proper sequence of establishing on an existing plant that has been operating without a coordinated maintenance program. The system installed in a plant may vary considerably from the basic plan and may never use some factors such as "standard practices" or "work measurement."

Some of our plants that have introduced better maintenance procedures and controls have cut their maintenance costs up to 20%. In many plants the effectiveness of maintenance labor has improved from the range of 40-45% to that of 70-75%. In some, even better results have been obtained. And in reduction of equipment downtime and increased productivity, all these plants have realized savings that alone have justified the cost. Of this we are sure:

> *Every one of these 18 basic tools can help trim your costs and boost output.*

I would like to emphasize one point. We don't aim just to *cut* maintenance costs. Anyone can do that, and get away with it for awhile. But eventually the accumulation of deferred maintenance will catch up with him.

Our purpose is to cut the *manufacturing cost of the product* and still maintain quality. Also, we're careful not to sacrifice employee safety. We've seen cases where zeal to attain low maintenance costs has ignored these important points, and wiped out expected savings.

Another Point: Experience has taught us that the best maintenance controls are of little value unless correctly used by maintenance supervisors. Also, higher management must give these controls its wholehearted support. *There is no substitute for good management and good foremanship.*

Now let's look at some of the 18 basic administrative tools for developing a successful maintenance program.

1. *Set Up A Proper Maintenance Organization*

Figure 4 shows a functional chart for a works engineering organization of over 200 men.

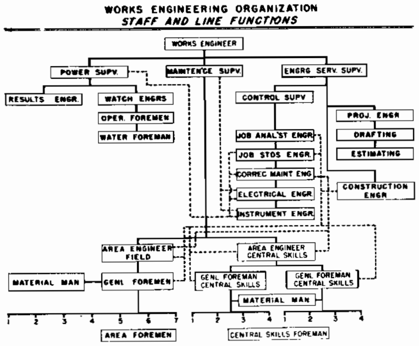


Figure 4

Usually du Pont plants have more than one product, so that they naturally fall into a number of production areas, each of which is under the supervision of an Area Production Supervisor. These areas may be more or less widespread and may have varied maintenance problems. A Maintenance Supervisor is assigned to each area and is responsible for all of the maintenance in that area. He is a member of the maintenance organization but works very closely with the Production Supervisor of that area to coordinate maintenance with equipment availability and production schedules.

The maintenance employees assigned to the area are those required for routine maintenance and may have skills including rigging, millwright and pipefitting. In addition to the area mechanics, there are also mechanics of various skills in the "central skill" organization. The men in this organization are normally those with pipefitting, pipe covering, rigging, carpenter, painting, sheet metal, electrical, instrument and welding skills. These men work either in the shop or in the areas where they can be efficiently scheduled through the preventive maintenance procedure to fit their activities into those of the area mechanics. The mechanics with the primary machining skill are normally assigned to the central machine shop and very rarely perform area work.

We have *found it almost a necessity* to establish a maintenance control group with the responsibility for procedures, training, upgrading, scheduling and other maintenance controls. Members of the line maintenance organization are responsible for the continued functioning of the plant and as such have many immediate problems such as safety and personnel administration which require immediate attention. In cases where we have made the line maintenance organization *also* responsible for establishing the control system and long-range analysis of maintenance cost, it has been generally unsatisfactory. This is

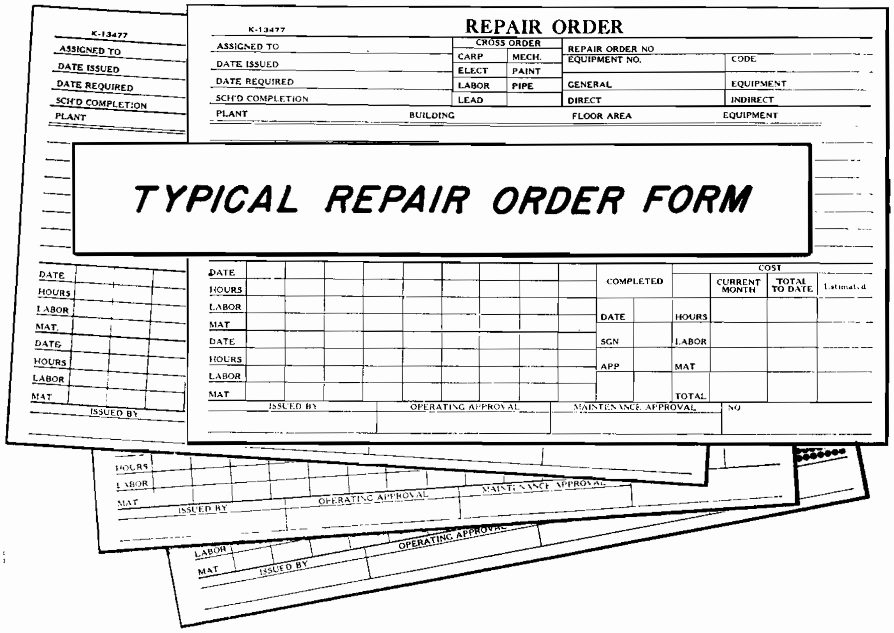


Figure 5

because the long-range planning is frequently set aside to "fight a fire today."

To repeat, it has been our experience that the *single greatest reason* for the *failure* of any maintenance *system* is the failure to establish a group whose responsibility is the continued successful operation of the system. By its very nature any maintenance system is restricting and achieves its success from the most efficient utilization of manpower. This requires continued effort and must be continually enforced by someone with that as his major responsibility.

2. *Establish A Work Order System*

Figure 5 shows a typical work order form. This is the "contract" between operations and maintenance for specific work to be performed. It is the *cornerstone of maintenance control* and forms the basis for equipment records, job analysis, work scheduling, and finally, work measurement. We issue serially numbered separate repair orders for work in excess of 4 man hours labor or $40 material charge. For lesser work we use an unnumbered patrol order form for which work is charged against the general equipment piece and account number. Patrol orders account for approximately 50% of total orders issued, but only 10% of total maintenance man hours. A third "blanket order form" is written periodically to cover repetitive, scheduled maintenance work which can be clearly defined, such as light bulb replacement, where the total job can be accurately determined. One of the biggest leaks is the tendency to set up a great number of blanket orders and give every foreman the number so that any miscellaneous jobs can be slipped into this category. If this is done, all information of time required, work done and unusual problems is completely lost.

3. *Keep Equipment Records*

Figure 6 shows a typical equipment record card. On most plants, each piece of equipment has a separate equipment record card. It normally contains a description of the equipment, equipment and building numbers and applicable drawing numbers. It also provides a space for the entry of maintenance performed on that piece of equipment. The information from each repair order is entered.

Where tabulating equipment is available, repair orders may be in the form of punched cards which can be conveniently stored and sorted to summarize and print maintenance costs and types of work whenever desired.

Manufacturer's manuals and guides are also maintained in this file along with copies of correspondence and other pertinent data.

4. *Analyze and Plan Jobs*

Each repair order must be carefully analyzed. In some plants this is the responsibility of each maintenance foreman. In others, the separate planning organization performs this work, leaving the foreman free for direct supervision, and personnel problems. In any event, the planner analyst, or foreman, must determine what is to be done, what parts are needed, and what tools and equipment to supply. He can then decide who does the work, and how many man hours it will take. In all cases the fore-

EQUIPMENT HISTORY CARDS

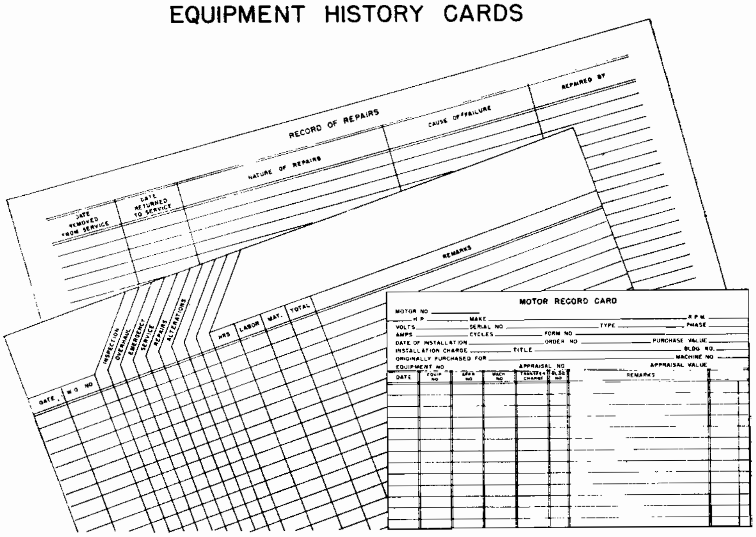


Figure 6

man reviews and approves the analysis and estimated time, as the responsibility for performing against the estimate is his.

5. *Make Weekly Forecasts*

Weekly forecasting is basically an agreement between maintenance and operating departments and the maintenance control group as to the probable days of the following week when major jobs will be done. We usually start scheduling on Wednesday, using preventive maintenance schedules as a basis.

The maintenance supervisor also reviews all repair orders and major overhauls for which material is available and determines with the production supervisor the priority of jobs for the coming week. On Thursday a weekly maintenance forecast for the following week is issued. Men assigned to patrol order and blanket order work are also listed.

On plants with good maintenance controls approximately 75% of the work can be forecast. Of the forecast work, approximately 85% can be performed during the week planned.

6. *Prepare Daily Schedules*

Typical daily schedule sheets are usually prepared before three o'clock for the following day by each foreman. Jobs scheduled for the following day show the estimated hours for each man assigned to that foreman for eight hours the following day. The estimated total hours for each job must agree with the estimate shown on the repair order. Patrol orders are not individually listed, but several men are assigned to this work, which is shown as "Patrol Order Work." Blanket order work is individually listed for those men assigned to that work. Any work which is performed the following day which is not included in the daily schedule is listed separately below a dividing line, so that later review will indicate the amount of emergency work.

We frequently find more than 15% emergency work and have established a goal of 4% emergency work for a typical well-run plant.

7. *Set Up Manpower Backlog Control*

As we have previously stated, there are only two ways to reduce maintenance cost:

a. Reduce maintenance labor.

b. Reduce maintenance material cost.

All of the maintenance controls established fail in their purpose unless they can permit such a reduction or achieve some other end such as decreased product loss. The monthly backlog report is one which shows the crew days of work, which exists as a backlog for each craft in the area. The purpose is to compare the backlog crew days with that of previous months to determine whether the work backlog is increasing or decreasing. A crew backlog of three weeks has proven satisfactory at most of our plants.

An example of the value of backlog control may be cited. One of our plants installed other excellent maintenance controls and procedures in Nov. 1954 and was working efficiently. Review of over-all maintenance costs in Aug. 1955 indicated a decrease in pipefitters from 21 to 16. The backlog control chart showed that the average craft backlog had been reduced from the excessive 6 weeks to 1½ weeks, which is below the optimum backlog of 3 weeks and where "fringe" maintenance work is performed. After inspection of those backlog charts, the pipefitting crew was further reduced to 14 mechanics resulting in a backlog increase to the normal 3 week amount.

8. *Establish A Preventive Maintenance Program*

Preventive maintenance consists primarily of doing maintenance when *you* want to rather than when the *equipment* wants to. Equipment left to its own devices seems to have a fiendish ability to do one of the following:

a. Fail after the regular day shift, thus requiring overtime.

b. All fail together without warning.

c. Break-down so that maintenance work is required on Christmas or New Year's day.

Through preventive maintenance we are able to perform most of our maintenance work during the daylight hours on the first shift and schedule it so that the available manpower is continuously busy rather than working in surges. This greatly decreases overtime costs. Another great advantage of preventive maintenance is that a whole equipment train can be maintained at one time rather than shutting down four or five times to maintain various equipment items in the train at different times. This greatly reduces product loss. An outstanding example of the amount of maintenance work that can be set upon a regularly scheduled preventive basis is one of our plants which has set up 60% of its maintenance work in this manner.

9. *Use Budgetary Control*

It would be difficult to establish a workable maintenance budget without the advantages of the eight preceding tools. They pinpoint 50-60% of our requirements. We prepare a maintenance budget on an annual basis, broken down into monthly subdivisions. The monthly budget varies according to seasonal requirements and vacations. It is not a fixed budget but a guide to staying within the annual budget, which *is* fixed. The budget may be set up by plant area or product if the maintenance responsibility is so established.

10. *Provide Material Control*

We use a form in the establishment of spare parts for each piece of equipment. Catalogs, drawings, correspondence and past experience are used to establish maximum and minimum amounts for all spare parts and extra machinery. Stores items are also accurately determined.

We make sure the system is

followed in *every detail.* This is important to build up confidence by the maintenance organization that materials will always be available. Otherwise the maintenance men will establish caches of critical items in remote plant areas—and this practice can prove costly. Sometimes such materials are exposed to corrosive gases and liquids. Also, the exact contents of the cache are seldom known, and much time is lost hunting a desired item. Adopt the type of parts distribution system you need—whether all centralized or with subdepots—depending on factors such as plant size and type. But, whatever you establish, be sure to use it.

11. *Plan Your Plant Shutdowns*

This is important for large-scale, continuous-operation plants where any lost production is costly. It is a good plan to determine what should be an optimum shutdown frequency. First, we determine the expected life of various critical components in each equipment group. Next, for each group we establish the shutdown frequency that permits the over-all minimum downtime. Then we fit in the planned shutdowns for other equipment groups. Such a program permits us to hold our maintenance organization to its smallest possible size and to operate with a minimum of maintenance overtime.

12. *Set Up Major Overhaul Procedures*

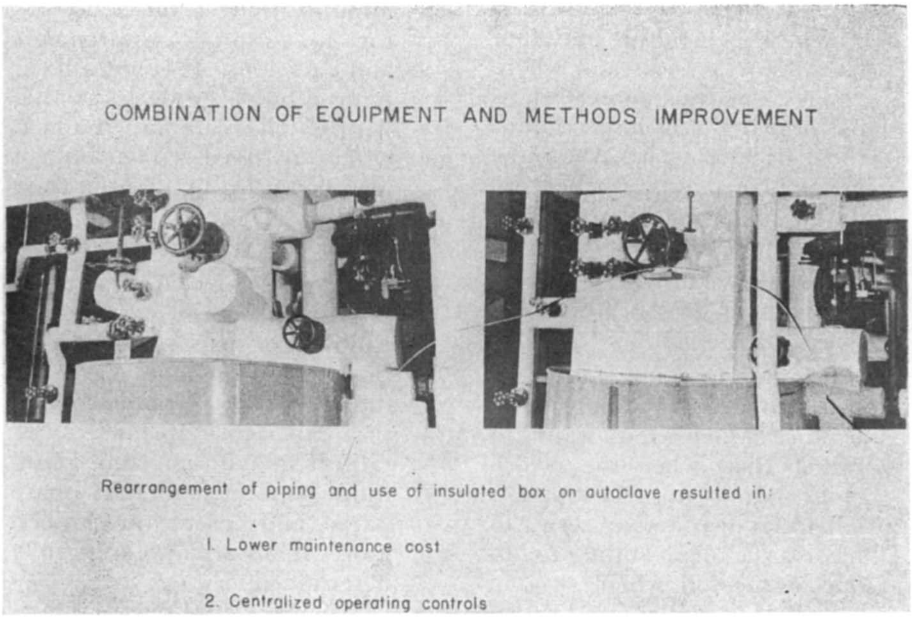
We believe there is usually "one best way" to disassemble, check, replace parts ,or reassemble any piece of equipment. We determine the best method through collaboration by our engineers, foremen, and maintenance men. After such study we write down the required crew size, and establish overhaul steps in proper sequence. Also, we list required tools and probable parts requiring replacement. We question every move, always looking for a better method or tool.

Our plants have discovered many ingenious methods to reduce overhaul time up to 50%. A typical example is that of having workmen enter an oven that's being slowly cooled, wearing air-cooled asbestos suits — thus saving precious hours.

15. *Improve Your Equipment*

Figure 8 shows two views of an autoclave at one of our plants. The left view shows the piping, valves and insulation as originally installed. Repeated removal of insulation was required for autoclave maintenance. The right view shows a piping rearrangement and use of an insulated box which is readily removable.

This is an example of what we mean by corrective maintenance. The long-range program is the simplification of the maintenance problem by making parts more accessible, or of better material and design to require less frequent replacement.



COMBINATION OF EQUIPMENT AND METHODS IMPROVEMENT

Rearrangement of piping and use of insulated box on autoclave resulted in:

1. Lower maintenance cost

2. Centralized operating controls

Figure 8

Design standardization is considered wherever practical. For example, an extensive survey of heat exchangers resulted in standardization that permits not only interchange of tube bundles, but also the corroded tube ends to be cut off for reuse in shorter exchangers.

This program must be planned, and competent engineers must be assigned to make improvement and *(more important)* follow the performance of test modifications.

16. *Train Your Supervisors*

There are many reasons for having a well-planned training program.

After accomplishing the first 15 steps it would be easy to conclude that adequate maintenance requires only perfunctory supervision. Such is not the case. We have learned that all levels of maintenance supervision must be trained to understand and use the maintenance controls. An important part of the training is to emphasize that the maintenance controls have the strong support of management.

Specifically, we have found it necessary to train foremen how to prepare work orders, equipment record cards, job analysis sheets, and so on. Our problem is to impress lower levels of supervision that preplanning and scheduling must precede the actual work if we are to provide good job effectiveness.

Again we must emphasize that the day of the "Bull of the Woods" foreman *is over.* The du Pont Company now has one engineer for every fifteen employees. Many of these engineers are serving as maintenance foremen and supervisors. The maintenance of continuous equipment requires a knowledge of process and production equipment, as well as specific "trade" knowledge.

17. *Train Your Maintenance Men*

The mechanics training programs are given to experienced mechanics to increase their knowledge of new equipment and raise their level of effectiveness. We have determined that an average increase in labor effectiveness of 11% results from training.

The training program has also been used at new plants where trained personnel were not available. It has been possible *within a four-month period* to train their new, inexperienced men to maintain the plant satisfactorily.

We believe that an important contributor to safety is job knowledge. Figure 9 shows the effect of training on major injuries to mechanics. The formal Company-wide program was started in 1951.

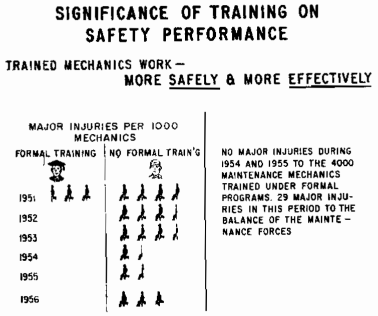


Figure 9

Each figure represents one injury per 1000 mechanics. As can be seen, none of the 4000 formally trained mechanics was involved in a major injury during 1954 and 1955. The 10,000 other mechanics were involved in 29 major injuries during this period.

The items covered by the Job Fundamentals portion of the programs include:

Mathematics
Measurement
Hand Tools
Grinding Wheels, etc.

Based on the tremendous increase in plant complexity mechanics will be maintaining plants in 10 years containing equipment our *engineers* do not visualize today. We must keep our mechanics in step with this technology or we will not be able to keep the magnificent new plants operating.

18. *Analyze Performance and Costs*

This is the job of continuing self-criticism of our maintenance operations. We have found that, regardless of the plant size or process, maintenance responsibilities can be divided into four broad functions:

Planning
Work Load
Cost
Productivity

Let us review the results of the analysis of a typical plant. Under each function are four factors which were analyzed with the results shown. Using statistical analysis and other study methods, the goal operating conditions for the plant were established and the current conditions were determined.

Summary of Factors.

Planning and Work Load

Factors	Current Percent	Goal Percent
Planning		
1. Personnel effectiveness	65	80
2. Man hours of work/week planned and forecast	50	85
3. Man hours of work/month—emergency	15	4
4. Man hours of work/month—overtime	8	2
Work load		
5. Crew weeks of current backlog	5	3
6. Crew weeks of total backlog	8.5	5
7. Man hours/month—preventive maintenance	10.	25.
8. Man hours/month—daily maintenance	90	75

Thus, we see that the labor effectiveness should be increased from 65 to 80%. The man hours of overtime work per month should be decreased from 8% to 2%. The current backlog should be decreased from 5 to 3 weeks. The man hours per month of preventive maintenance work covered by major overhauls should be increased from 10 to 25%.

Next we show the functions of cost and productivity.

Factors	Current Percent	Goal Percent
Cost		
9. Decrease or increase maintenance unit cost	+15	−10
10. Maintenance cost as percent of investment	10.5	6
11. Maintenance $—direct and general maintenance	65	85
12. Maintenance $—indirect maintenance	35	15
Productivity		
13. Ratio delay	55	75
14. Forecast effectiveness	40	75
15. Mechanical downtime	12	3
16. Increase or decrease in units of product/maintenance dollar	−17	+12

Here we see that during the past year there has been an increase of 15% in maintenance cost. Through continued effort we hope to reduce this 10% during the next year. We see that we are spending 35% of our effort for indirect maintenance such as valve relocation, service to operations, and other items that are not specifically required to keep the plant operating. This should be reduced to 15%

An important item is that of mechanical downtime which should be decreased from 12% to 3% to increase productivity.

A plant with limited procedures and controls and no formal training will probably have a labor effectiveness of 20 to 40%. Using good controls and procedures, mechanics training and measurement, the labor effectiveness will normally be in the 80-90% range.

The accomplishment is not easy. *We* can do it. *You* can do it. We call it *"ENGINEERED MAINTENANCE."*

Question No. 1—What is a Formula for Balance Between Maintenance, Labor Cost and Equipment Replacement?

A. S. Jackson

A SINGLE formula for the balance of labor, maintenance and machinery for all mills would probably have no useful meaning but a method of obtaining a formula for a particular mill is practical.

Let's take machinery only first:

A system of recording and cataloging cost so that a general and detailed knowledge as to where expenditures go is essential. One of the most workable systems that I have seen consisted of indexing the machines and sub-indexing the parts of machines on cards. Replacement data and service is kept directly on the card.

If a file is kept, two important features show up quickly. Description, serial number, etc. are immediately available without trying to read some corroded nameplate. The service of an item per dollar becomes apparent.

Do any of you have in your mills bearings that are in hard to reach places that seem to outlast accessable, easy to maintain bearings on similar service? Greasing programs could be at fault. Records might indicate that such conditions exist.

Could a two foot troughing conveyor idler that has the same roller bearing as a six foot flat idler have a little more bearing capacity than needed? A lighter ball bearing idler may give more service per dollar.

On the other hand, the ball bearing idler may have a lighter frame that fails too soon from corrosion. Only your records of your mill can tell you which is best.

When rating the performance of the combination of labor and machines, we must first establish a common performance scale.

Let's call the term "operating efficiency" and define it as the percentage relation of fertilizer actually produced in a given period of time as compared to what could be produced if it were possible to operate 100% of the time at the same nominal rate of operation: For example, if a plant could operate under some specific conditions at 30 tons per hour then for 100% of the eight hour day it should make 240 tons. If during an actual eight hour day the plant produces only 160 tons with time lost in starting, clean up, etc. the rating for that day would be 67%. Efficiency could be rated in shifts, days or weeks or grades, it does not matter as long as comparative records are in the same time intervals.

What would low or variable operating efficiency show? It might show the real cost of inadequate machinery that keeps breaking down, it might show the real cost of formulas that look cheap on paper but are difficult to run, it might show poor supervision. Production mills should give a relatively uniform answer. It gives a performance target for operating personnel to aim at.

Bagging mills will probably give more erratic answers as weather becomes a contributing factor.

In order to get a picture of the operation the results of the records should be put on graphs. It is too easy to get lost in a mass of figures and lose the relation of contributing figures.

On any route to decrease cost of production, a starting point must exist. A few simple records will go a long way in establishing this point.

Robert E. Robinson

THE formula we seek is some correct method that will yield for various alternatives a correct comparison of total costs corrected for the time value of money.

When you make an investment you want to make the best possible use of your capital funds. You may buy stocks in the finest corporations having the best management records. Sometimes, however, you may be reluctant to invest funds in your own business even though competitors may invest in the same industry in the same location. You need a way of measuring the merit of proposed investments. Without it, we often see equipment many years beyond the proper retirement time still in operation, although the owner may buy a new automobile every 2 or 3 years and may own stock in companies who do accept the concept of equipment obsolescence.

This idea of equipment obselescence can be difficult to accept. As an extreme example, a few years back Ford Motor Company discarded after just one year's use a great deal of automatic production machinery that had cost approximately $20,000,000. Why? Most of us would believe that Ford knew what it was doing. Obviously, a decision was reached that the best economic course from that point forward was to discard the equipment and to follow some other alternate course. The decision did not turn on the original cost of the equipment or its age, condition, or book values. The decision was based on future considerations and the past was important only as it might affect the future.

We must recognize that in different situations the economic factors may vary widely and that any decision in a given case must be based on the considerations pertinent to that case. A general understanding of the principles of engineering economics and financial mathematics is needed to surely analyze problems of maintenance and replacement. References are given which deal thoroughly with these principles.

What Can You Do?

Moving to a practical, personal appraisal, we might ask "What can we do, what are our objectives in a maintenance and equipment replacement program?"

Our objective is the lowest total cost consistent with getting the job done. This requires knowing what the costs are. Painfully detailed bookkeeping and record making can cost more than it is worth sometimes, and I would submit that a simple practical system sometimes using estimates and approximations will often serve as well. Many times general questions and answers will yield the same ultimate information.

"How much does leakage and spillage around an old piece of equipment cost to clean up every day?"

"How much does incorrect analysis due to poor equipment cost each year?"

"Can a man be eliminated at this location by installing a certain piece of equipment?"

"How expensive is a breakdown costing three days production during the busy season?"

A Simple Program

Three requisites for a sound maintenance and replacement policy might be: 1) a method for comparing various alternate courses of action, 2) a proper organization, 3) a proper attitude.

Some one man should have responsibility. The first steps should be simple ones, and the first programs should be so planned that it can be finished and some immediate benefits obtained promptly. A beginning might be a list of all items of equipment in the plant, with notations as to troubles associated with each. A second list might detail duties of each man, with the ultimate goal of reducing labor and increasing efficiency. A "want list" of needed projects serves to keep all possible investments before the management, so that none will be overlooked and so that the best and most needed ones will be selected first. For the advanced program, detailed studies and continuing analyses will be desired.

The proper attitude is a simple one: to seek the truth. Much misinformation is available, most of it free. We must avoid false assumptions, we must be sure to solve the right problem.

Regarding the methods of making engineering economy studies, this paper will give a short, simple example and a list of very good references. Such studies are continuing ones, and a decision to defer action carries with it the opportunity for further future study and the possibility of a different decision at a later time. Such studies must extend beyond direct maintenance and operating costs to yield comparisions of total cost.

Preventive Maintenance Suggestions

The hoped for objectives of maintenance include prevention of breakdowns, prevention of unnecessary wear and damage to equipment because of neglect, attainment of maximum economic useful life of equipment, preservation of safety, and the attainment of lowest possible total operating cost.

Adequate equipment records must be kept so that all repair information is immediately and accurately available. Equipment files should be maintained separately so that all repair information can be removed only by authorized personnel; and it should preferably be signed for and traced to insure prompt return. A properly classified numerically indexed filing system is a big help, and the use where possible of reproducible originals helps by making copies easily available for use outside the office.

All maintenance is preventive. The simplest steps are regular cleaning and visual inspection, followed by lubrication or other routine service. The next type of maintenance operations includes in addition to the above, checking operations such as measurements, partial disassembly and inspection, and simple adjustments. Then we have painting and replacement of packings and normally wearing items. All of these steps should be scheduled and carried out regularly. Replacement of heavier parts and major adjustments should also be anticipated and scheduled so that the work can be done during scheduled down-time periods with sufficient time to properly do the work at a minimum of cost. Overhaul is the least frequent occurence, but sometimes is very much to be preferred to a series of piecemeal emergency repairs during unscheduled breakdowns.

Equipment should not be babied, and unnecessary work should never be done. As records and experience grew, a continuing study might reveal a pattern offering improved maintenance at less cost.

Preventive Maintenance Considerations

Equipment must be originally selected to perform under various duty requirements, and facilities also fall under different classes. A possible classification follows:

Duty Ratings	Classes of Operation
1. Stand-by Duty	A. 8 Hours per Day, Seasonal Operation
2. Light Duty	B. 8 Hours per Day Year Around, or Equal
3. Moderate Duty	C. 16 Hours per Day Year Around, or Equal
4. Constant Duty	D. 24 Hours per Day Year Around
5. Severe Duty	

This classification points out that maintenance policy begins with the selection of the equipment. The availability of scheduled maintenance periods is not the same from plant to plant, and the costs of unscheduled shut-downs vary widely. Preventive maintenance is done before it becomes absolutely necessary.

A table of estimated service lives, cycles of major overhaul, and approximate maintenance cost during service lives might serve as a starting point to further consider the variations encountered:

Equipment	Duty Rating	Class of Operation	Average Life	Cycle of Overhaul	Est. Maintenance Cost During Life
Mixer, Batch	3	B	10 Yrs.	5 Yrs.	100%
Screens	3	B	15 Yrs.	1½ Yrs.	60%
Elevators, Bucket	3	B	15 Yrs.	7½ Yrs.	75%
Conveyor, Belt	3	B	20 Yrs.	10 Yrs.	50%

Etc. (Note: Above figures are hpyothetical, for example only.)

Table I

Year of Service	Salvage Value End of Year	Loss of Salvage During Year	Cost of Losses During Year	Maintenance Cost During Year
Plant A	(1)	(2)	(3)	(4)
0	$6500 (New)	$ —	$ —	$ —
1	4100	2400	0	363
2	2670	1430	100	2618
3	1500	1170	200	386
4	525	975	300	499
Plant B				
0	$6500 (New)	$ —	$ —	$ —
1	4220	2280	0	424
2	2920	1300	75	490
3	1945	975	150	2725
4	1165	780	225	507
5	515	650	300	606

All scheduled maintenance is preventive. The simplest steps are regular cleaning and visual inspection, followed by lubrication or other routine service. The next type of maintenance operations include in addition checking operations such as measurements, partial disassembly, and simple adjustments. Then we have painting and replacement of packings and normally wearing items. All of these steps should be scheduled and carried out systematically. Replacement of heavier parts and major adjustments should also be anticipated and scheduled so that the work can be done during scheduled down-time periods with sufficient time to properly do the work and at a minimum of cost. Overhaul is the least frequent occurence, but sometimes is indicated very much in preference to a series of piecemeal emergency repairs during unscheduled break-downs.

The economic justification for the added expense of good preventive maintenance requires economic evaluation just as would any other investment. Clearly, policies might justifiably differ for a plant using a piece of equipment performing moderate duty in a seasonal operation as compared to a severe duty requirement operated the year around. The extreme case is reached in the case where the primary unit must have a stand-by unit available to take over the operation during down-periods.

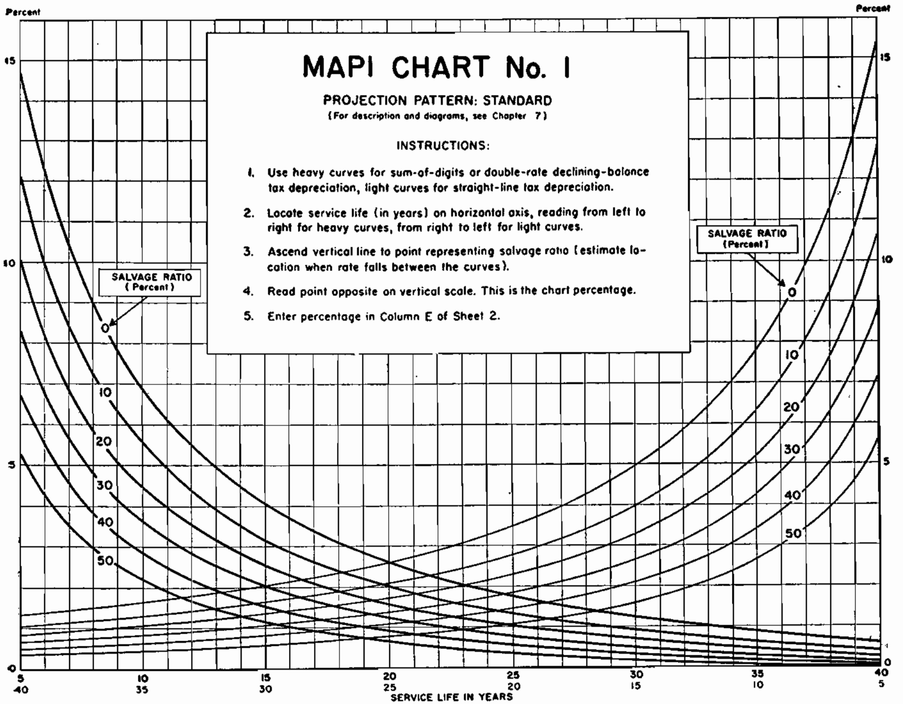
Equipment Replacement Considerations

It is beyond the scope of this paper to discuss in detail the highly technical subject of equipment replacement economics. Reference (3) "Business Investment Policy" prepared by Machinery & Allied Products Institute, Washington, D. C. represents advanced and very competent work in this field, and offers both the exhaustive theoretical study and a greatly simplified means of application. For the less technically inclined, Reference (1) "Principles of Engineering Economy" by Eugene L. Grant is a recognized engineering college textbook, although the chart and tabular method developed in Reference (3) is actually easier to apply if the theory is accepted prima facie.

The basic principle involved in an investment study is the setting down in financial terms of as many factors as possible, the reduction of these terms to some equitable value, and the comparison of two or more possible courses of action. Every effort must be made to compare the best courses of action, never overlooking a better possibility. The methods developed in References (1) and (3) take into account the time value of money, income tax efforts, salvage values, repair costs, value of improvements available now or at some future time, various service lives, and other pertinent factors. Most important of all, both works strive toward the goal of insuring solution of the right problem and of avoiding incorrect solutions through false assumptions or calculations.

"Irreducibles"

Under no circumstances will a system or method make the final decision. The system is a means to help reach the end, but final evaluation must always consider all of the loose ends, close and pertinent, and random and remote. Even when the situation looks hopeless from lack of data, a real effort to make a study will have greater assurance of giving the correct economic solution than would a completely blind guess. As a continuing program is developed, many of the seemingly inaccessible



MAPI CHART No. I

PROJECTION PATTERN: STANDARD
(For description and diagrams, see Chapter 7)

INSTRUCTIONS:

1. Use heavy curves for sum-of-digits or double-rate declining-balance tax depreciation, light curves for straight-line tax depreciation.
2. Locate service life (in years) on horizontal axis, reading from left to right for heavy curves, from right to left for light curves.
3. Ascend vertical line to point representing salvage ratio (estimate location when rate falls between the curves).
4. Read point opposite on vertical scale. This is the chart percentage.
5. Enter percentage in Column E of Sheet 2.

Copyright, 1958, Machinery and Allied Products Institute items of data will come to light either from actual record or improved estimates.

Preventive Maintenance Problem

Records of tractor shovel operation of a large company indicate that in plant A tractors have had average service lives of 8,000 hours and four years, while tractors in plant B have had average service lives of approximately 10,000 hours and five years. Company policy has been to make one major overhaul of each machine during its service life, and in plant A this overhaul has come at the end of the second year of operation, while in plant B it has come at the end of the third year. Average expenditures for maintenance for each plant and average estimated salvage values at the end of each year are given in Table 1 on page 12.

It is noted that Plant B has higher maintenance cost, but it is desired to determine if this additional expenditure on preventive maintenance actually results in a lower annual average total cost of tractor operation. Interest rate is 10%. The time-adjusted annual averages of Capital Cost and Operating Inferiority will be calculated and the totals tabulated, for periods from the start at 0 years to the end of each year. Cost of losses is from breakdowns.

	Interest on Opening Salvage Value for Year Indicated (5)	Capital Cost for Year Ind. (2)+(5)	Present Worth Factor For Yr. Indicated	Present Worth of Capital Cost for Yr. Ind.	Present Worth of Cap. Cost for Period Yr. 0 to Yr. Ind.
Plant A		(6)	(7)	(6) x (7) = 8	(9) (Col. 8 Cumulated)
1	$650	$3050	.909	$2770	$2770
2	410	1840	.826	1520	4290
3	267	1437	.751	1078	5368
4	150	1125	.683	768	6136
Plant B					
1	$650	$2930	.909	$2660	$2660
2	422	1722	.826	1420	4080
3	292	1267	.751	951	5031
4	195	975	.683	666	5697
5	117	767	.621	476	6173

	Capital Recovery Factor for Period Ending with Yr. Indicated	Time Adj. Ann. Av. Cap. Cost for Per. End.w.Yr. Ind. (9) x (10)	Time Adj. Ann. Av. Cost of Losses for Per. Ending w.Year Indicated	Time Adj. Ann. Av. Maint. Cost for Period Ending w. Year Indicated	Total Time Adj. Ann. Av. Cost (11)+(12)+(13)
Plant A	(10)	(11)	(12)	(13)	(14)
1	1.100	$3050	$ 0	$ 363	$3413
2	.576	2475	48	1435	3958
3	.402	2160	94	1120	3374
4	.315	1930	139	984	3053
Plant B					
1	1.100	$2925	$ 0	$ 424	$3349
2	.576	2350	36	232	2618
3	.402	2020	70	1140	3230
4	.315	1800	104	1001	2905
5	.264	1620	135	936	2691

The results show that Plant B is achieving a lower total average cost, $2691 against $3053. Also shown is the fact that Plant B has its lowest annual average cost at the end of the two year period when the value is $2618. Assuming that the data used and the assumptions applied are sufficiently correct, and that the tractor shovels were readily marketable at the salvage values assumed, Plant B could consider replacement of its equipment after two years service.

In practice, expenditures are spread out over each year. For the purposes of analysis they are treated as if they occurred at the start of the year. Obviously, the results of an analysis such as the one above must be "shaded" with consideration of the irreducible factors proviously mentioned.

It is beyond the scope of this paper to attempt to deal with equipment replacement studies, but the above analysis represents a first step. If the figures for Plant A represented the present "Defender" equipment, which we will assume could be replaced exactly and the entire cycle repeated by what we will call Challenger A, and the figures for Plant B represented another Challenger B, it would appear that the best investment would be to select Challenger B, which would have lower annual average total costs for all periods of operation from 1 to 4 years, and an additional economical life in the fifth year which Challenger A does not offer.

The entire subject is treated exhaustively in References (1), (2), and (3). See also Forms pages 14 and 15.

References

(1) Grant, Eugene L. "Principles of Engineering Economy," The Ronald Press Company, New York, N. Y.
(2) Tergorgh, George, "Dynamic Equipment Policy," McGraw-Hill Book Company, Inc., New York, N. Y.
(3) Tergorgh, George, "Business Investment Policy," Machinery & Allied Productions Institute, 1200 18th Street, N. W., Washington 6, D. C.
(4) MAPI, "Realistic Depreciation Policy," Machinery & Allied Products Institute, 1290 18th Street, N.W., Washington 6, D. C.

Walter J. Sackett

HERE, indeed, is a good question, but one that certainly does not appear to be easy to answer. Volumes, as you are well aware, have been written on the subjects of capital investment, maintenance, depreciation and all the other important cost considerations as they relate to plant equipment. Yet, to my knowledge, not one of these contains a formula that may be applied to any one particular industry within the required limits of accuracy. That this situation exists is perfectly understandably when one considers the fact that each one of the vast number of industries that go to make up our great American Industrial Economy, has a different set of conditions under which it operates. While it is true that the basic fundamentals are the same, there are, nevertheless, significant differences in their adaptation by each industry segment to best fit its own particular requirements.

Let us attempt, to answer this question as it relates to our own Fertilizer Industry by taking it apart piece by piece in its logical order to see what each part contributes to the whole. First and foremost, let us consider capital investment, which in this particular case means the purchase and installation of a machine or process for the fertilizer plant. To be more specific, let us assume this to be a process to be used for the manufacture of granulated fertilizer compounds. On this subject, it must be understood that a great deal of responsibility rests on the shoulders of those who make the final decision as to the type and quality of equipment that will be purchased.

PROJECT NO.________ SHEET 1

SUMMARY OF ANALYSIS

(SEE ACCOMPANYING WORK SHEETS FOR DETAIL)

I. REQUIRED INVESTMENT

1 INSTALLED COST OF PROJECT $______ 1
2 DISPOSAL VALUE OF ASSETS TO BE RETIRED BY PROJECT $______ 2
3 CAPITAL ADDITIONS REQUIRED IN ABSENCE OF PROJECT $______ 3
4 INVESTMENT RELEASED OR AVOIDED BY PROJECT (2+3) $______ 4
5 NET INVESTMENT REQUIRED (1−4) $______ 5

II. NEXT-YEAR ADVANTAGE FROM PROJECT

A. OPERATING ADVANTAGE

(USE FIRST YEAR OF PROJECT OPERATION)*

6 ASSUMED OPERATING RATE OF PROJECT (HOURS PER YEAR) ______ 6

		Increase	Decrease	
	EFFECT OF PROJECT ON REVENUE			
7	FROM CHANGE IN QUALITY OF PRODUCTS	$	$	7
8	FROM CHANGE IN VOLUME OF OUTPUT			8
9	TOTAL	$ A	$ B	9
	EFFECT OF PROJECT ON OPERATING COSTS			
10	DIRECT LABOR	$	$	10
11	INDIRECT LABOR			11
12	FRINGE BENEFITS			12
13	MAINTENANCE			13
14	TOOLING			14
15	SUPPLIES			15
16	SCRAP AND REWORK			16
17	DOWN TIME			17
18	POWER			18
19	FLOOR SPACE			19
20	PROPERTY TAXES AND INSURANCE			20
21	SUBCONTRACTING			21
22	INVENTORY			22
23	SAFETY			23
24	FLEXIBILITY			24
25	OTHER			25
26	TOTAL	$ A	$ B	26

27 NET INCREASE IN REVENUE (9A−9B) $______ 27
28 NET DECREASE IN OPERATING COST (26B−26A) $______ 28
29 NEXT-YEAR OPERATING ADVANTAGE (27+28) $______ 29

B. NON-OPERATING ADVANTAGE

(USE ONLY IF THERE IS AN ENTRY IN LINE 4)

30 NEXT-YEAR CAPITAL CONSUMPTION AVOIDED BY PROJECT: 30
A DECLINE OF DISPOSAL VALUE DURING THE YEAR $______ A
B NEXT-YEAR ALLOCATION OF CAPITAL ADDITIONS $______ B
TOTAL $______

C. TOTAL ADVANTAGE

31 TOTAL NEXT-YEAR ADVANTAGE FROM PROJECT (29+30) $______ 31

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* For projects with a significant break-in period, use performance after break-in.

PROJECT NO.________ SHEET 2

III. COMPUTATION OF MAPI URGENCY RATING

32 TOTAL NEXT-YEAR ADVANTAGE AFTER INCOME TAX (31−TAX) $______

33 MAPI CHART ALLOWANCE FOR PROJECT (TOTAL OF COLUMN F, BELOW) $______ *

(ENTER DEPRECIABLE ASSETS ONLY)

Item or Group	Installed Cost of Item or Group A	Estimated Service Life (Years) B	Estimated Terminal Salvage (Percent of Cost) C	MAPI Chart Number D	Chart Percentage E	Chart Percentage × Cost (E × A) F
	$					$
					TOTAL	$

34 AMOUNT AVAILABLE FOR RETURN ON INVESTMENT (32−33) $______

35 MAPI URGENCY RATING (34÷5) · 100 %______

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* Since the chart allowance does not cover future capital additions to project assets, add an annual proration of such additions if any, to the figure in Line 33.

(SPECIMEN)

DIGEST OF PROJECT REPORT

COMPANY ______________________ DATE ______________________

DEPARTMENT ______________________ PROJECT NO. ______________________

ANALYST ______________________

I. DESCRIPTION OF PROJECT

PROPOSED ACQUISITIONS

MANUFACTURER			
TYPE AND SIZE			
MODEL NO.			
COST OF ITEM	$	$	$
INSTALLATION COST	$	$	$
TOTAL COST	$	$	$

CHANGES IN OPERATIONS RESULTING FROM PROJECT

INVESTMENT RELEASED OR AVOIDED BY PROJECT

II. RESULTS OF ANALYSIS

(FROM SUMMARY FORM)

INSTALLED COST OF PROJECT (LINE 1)	$
NET INVESTMENT REQUIRED (LINE 5)	$
NEXT-YEAR OPERATING ADVANTAGE (LINE 29)	$
MAPI URGENCY RATING (LINE 35)	%

III. COMMENT AND RECOMMENDATION

APPROVED BY ______________________ DATE ______________________

Experience has taught these men the importance of making a thorough investigation of the equipment market before the purchase is made, because they know that similar equipment from various manufacturers can and does have widely varying performance records. They are also careful to secure complete and accurate production and maintenance cost data from users of similar equipment before reaching their own decision. These men well realize that the competitive future of the plant in which this new process is to be used, can, and in a great many cases, does importantly hinge on the judgment and wisdom of their decision.

There can be little doubt that the best buy in the long run is a process that can be depended upon to give optimum production efficientcy over a period of, say, ten years. Optimum production efficiency in this particular case means a process that is capable of sustaining its rated capacity without unscheduled down-time and consistently producing at the lower overall unit cost. A process capable of producing this kind of a result will be found to be well designed, generously proportioned, strongly built, adequately powered and provided with heavy duty roller bearings or other oversize performance-proved anti-friction units. In short, a process that has the stamina and required long life expectancy built into its every part . . . a process that will give years of maximum production efficiency with a bare minimum of produtcion interruptions and maintenance expense.

To illustrate the close relationship that exists between design and production efficiency, I should like to cite, at this time, actual case histories which have been taken from the files and made available to us by two unrelated fertilizer manufacturers. The first of these cases covers the performance record of a well built process for the three peak production months of March, April and May of 1958. This process had been in service at that time for a period of something over four years. The operating records shows that this unit scored a 97.11% rate of production efficiency for the full three month period.

The second of these cases covers the performance record of a similar unit, but of inadequate design, operating during the same three months of March, April and May of 1958. This latter process had been in service, at that time, for a period of less than three years. The operating record, in this case, showed that the unit of inadequate design operated at a production efficiency of only 79.59% for the same three month period. The resulting comparisons of these factual case histories show that the overall production efficiency rate of the strongly built unit exceeded that of the light weight design by more than 22%.

What became of this loss of production, especially at that time of year, is a good question. Certainly, it can be definitely stated that the fertilizer tonnage, which this produtcion loss represents, can never be regained by this manufacturer. And, too, there is always the possibility that it could and might have caused some farmer and dealer accounts to seek their fertilizer requirements from other sources of supply. Furthermore, it should be pointed out that there is one very important fact that is *not* brought out by these case histories; namely, that the older but heavier built process still retains a conservative 60% of its original life expectancy, where as in the case of the other unit, its useful life, because of highly excessive maintenance expense, is about exhausted and is scheduled to be replaced before next spring's fertilizer production program gets under way.

And now, in conclusion, let us reassemble this Question #1 that we earlier took apart and, in the light of the foregoing, place realistic values on its component parts before we attempt to see where they best fit back into place. What is a formula for balance between maintenance cost and equipment replacement? As I see this question, a whole lot depends on which way you want to go. Do you want to follow the path of a smaller down payment in the form of capital investment with high and loaded carrying or maintenance charges, or does it seem more logical to raise the capital investment ante a bit to obtain the best long term value? I have a lot of support in the Fertilizer Industry when I say that I wholeheartedly recommend to you that the latter course be followed.

Wayne W. King

HERE we are again at the famous Fertilizer Round Table. It is a privilege for me to be here among so many of my friends and talk shop in our language of mutual understanding.

I would like to visit with you a few minutes and discuss "Planned Preventative Production Engineered Maintenance." The figures I have collected prove that this effort pays dividends and especially with reference to our granular efforts. Here we have rapid, corrupt corrosion and erosion aided by various chemical reactions and possible mild electrolysis plus an occasional "Jug-Head" on the payroll who hides the equipment Instruction Books.

Instruction Books are my pet peeve. Who is the gentleman that gets these books and hides them? Almost every equipment manufacturer takes great pride in the editing, compilation, printing and mailing of these books. Please read and re-read these and see that a copy is available to your key personnel at the "Do It" level. Follow these instructions as the "father" of the equipment knows best.

To attempt to give you an exact breakdown of the proper balance between Preventive Maintenance, Bare Operative Maintenance and Equipment Replacement has been proven impractical. Geographic and climatic factors and differences in bookkeeping practices will obviously alter the desired formula for success.

Differences in percentage of maintenance to total labor vary from 5% to 60%. Do not worry if you are high or low on this scale, providing your cost per ton is within reason. Many other factors add to the confusion of comparing one plant with another—such as varying labor rates and Union Rules. Seriously, the degree of automation is a tremendous factor as are the hours of operation each day, week, month and year—all of which affect the cost per ton.

A coined phrase *adequacy* might aid our thinking:

Adequacy of maintenance means different things to many people, but it must be adequate to keep the operating hours high in order to keep the cost low. Then there is the man who needs new equipment; knowingly or unknowingly if the maintenance is too high, he is paying for it but not getting it, which brings up the definition of Obsolescence. On this we do not all agree; what seems obsolete to me may not seem so to you. Some folks might consider equipment functional—i.e., in fair repair; so CAN WE AFFORD to replace a piece of equipment OR CAN WE AFFORD NOT to replace it?

I have surely enjoyed this subject. In fact, I became so interested that I have carried by questionnaire into multiple industries and reached some very definite conclusions.

Good Housekeeping and a *Planned Maintenance* is your most profitable investment. Plan ahead.

Question No. 2—Will the Cost of a Good Preventive Maintenance Program Be Justified When it Produces a Minimum Amount of Down Time? What Should a Good Procedure Be?

Joseph L. Prosser

WE think the answer to this question is a definite *Yes.* A well-organized and administered preventive maintenance program can be justified from the standpoint of keeping down-time and production losses to a minimum.

The basic purpose of such a program is, of course, to prolong the periods between major equipment breakdowns through a carefully planned and thoroughly understood scheduling of duties to be performed by the maintenance crew. These duties would include such things as the cleaning of the equipment at the end of each production period and the lubrication, painting and adjustments of the machinery, in accordance with a definite schedule. Last, but certainly not least, a thorough periodic inspection of all moving or other wearing parts should be included as part of this program in order to determine as accurately as possible when a down-period should be scheduled.

Three characteristics of a modern fertilizer plant make unscheduled shut-downs completely disastrous. First, wages are much higher than they were years ago. Now, the men, standing around awaiting a repair, earn in many cases more than the cost of the repair. Second, the Industry now tends toward continuous processes. There is no such thing as a minor breakdown on a continuous process. Almost any stoppage causes two to four hours of lost production while labor costs, power costs and, often, fuel costs go on. Third, we now ship direct to trucks, which are often customer owned and operated. A farmer can become quite annoyed when he is tenth in line and no bags are loaded for an hour or two while a packer, sewing machine or shipping elevator is being repaired.

To expect a job to be performed by the maintenance department, it is highly important that it be provided with the right tools and equipment for doing its work. And, too, it should have an adequate inventory of equipment replacement parts at its disposal if and when a major breakdown does occur. For all intents and purposes, the investment made in keeping an adequate inventory of spare parts in the factory storeroom should be looked upon as a justified insurance cost against prolonged production losses which might otherwise be inevitable.

On this subject of spare parts and their importance in the elimination of prolonged down-periods, let me tell you what I witnessed at a fertilizer plant not too long ago. My work at this plant took several days to complete. The second morning, I arrived at the plant to find everything at a standstill and the yard full of trucks not getting serviced. Upon inquiring as to the cause of the stoppage, I was told that a certain elevator part had broken and they had no spare they could use. A new part had to be made which together with the dismantling and re-assembly time caused the plant to be out of use for 18 hours. The management of this operation admitted to me that the fixed plant expenses were $300 per hour which, in this case, had amounted to over $5,000. Here, mind you, was a $5,000 loss for the want of a spare part that cost less than $50.

From the foregoing example and, undoubtedly, you have seen cases similar to this, I am sure we will all accept the premise that an adequate spare parts stock is an absolute must to keep a plant operating in a satisfactory manner. Then, the next question is, what do we mean by adequate? We think it means, in this case, the keeping of a spare parts stock that in dollar value amounts to approximately 10% of the cost of the plant equipment which it is to service.

Summarizing, then, we find that the prerequisites of a sound program of this kind briefly consist of:

1. A carefully planned and thoroughly understood schedule of duties.
2. A well-trained maintenance crew.
3. Providing the right maintenance tools and equipment.
4. A sufficient supply of replacement parts.

There is one last thing I might add and that is the posting of a weekly chart in the maintenance office or shop, which gives a complete and detailed run-down of all the duties and schedules included on the maintenance itinerary.

With a well-planned program such as this, you will find that unscheduled downtime will just about become a thing of the past.

Sam E. Shelby

PREVENTIVE maintenance is the correct operation and servicing, inspection, detection, and correction of the causes of equipment failures before they occur or develop into major defects. The purpose of a good preventive program is to keep equipment in the best possible operating condition and ready for use at all times. The result of such a program is the saving of time, labor, and expense.

The driver, operator, or foreman is the most important single factor in a successful preventive maintenance program. Each driver, operator or foreman is generally required to perform certain daily or weekly maintenance services on the equipment or area of which he is a supervisor. These daily services fall into three groups: before-operation, during operation, and after-operation. The purpose of the before-operation is to determine whether the condition of the equipment has changed since it was last operated and to make sure that the machinery is ready for operation. The purpose of during-operation services is to report or correct, any deficiencies in performance or other signs of abnormal operation. The purpose of the after-operation services is to insure that the equipment is ready to operate at anytime or to report any mechanical deficiencies that may result in further damage if operation is continued prior to correction.

The second most important factor in a good preventive maintenance program is the regularly scheduled service and maintenance inspection generally performed by unit mechanics. The intervals of prescribed preventive maintenance services are considered to be the minimum requirement for normal operation. Under unusual conditions it may be necessary to perform services more frequently. Maintenance services should be scheduled at regular intervals and every effort made to assure that each part of equipment undergoes its preventive maintenance services at the scheduled time. The unit mechanic is also responsible for aiding the operator in servicing his equipment on the job.

The third link in a good preventive maintenance program is the factory or Plant Manager. It is his responsibility to supervise the preventive maintenance services throughout his organization. The success of such a program depends on how well he fulfills his responsibilities. Some of the most salient essentials of these responsibilities are, educating personnel to perform duties regularly and properly, proper operation of equipment, securing necessary tools and competent personnel, preventing abuse to equipment, and selection of equipment.

"Down Time" may be designated as the period which has not been planned, in which a piece of equipment or plant is unable to perform work. This "Down Time" is generally a result of the malfunction of one or more integral parts of the machine or process. "Down Time" causes a decrease in the manufacturing efficiency and results in excessive maintenance.

The cost of "Down Time" will vary with the size of the operation and the importance of a piece of equipment. First, the cost to get a plant or machine back in operation after a breakdown is generally more expensive than normal repairs because of damage done to adjacent equipment and the time of breakdown. A planned inspection and repair is performed in normal working hours and more discretion is used in repair and replacement of parts. Second, the breakdown usually causes loss or damage to the product being manufactured which might be more expensive than the cost of repair. Third, as a rule the breakdown occurs when operating personnel are on the job and their production effectiveness becomes nil. Fourth, the untimely breakdown might occur to equipment used in servicing customers which might cause a loss of a customer or strained relations. This is most difficult to put in dollars and cents except to say that our customer is the most important individual in our business. Fifth, excessive breakdowns cause more maintenance personnel, more spare parts on hand, more overtime pay, and more loss of sleep and gray hairs. Sixth, quite often a breakdown causes an injury to an employee which again cannot be evaluated by the dollar.

A good preventive maintenance program should be established, and followed closely and all personnel realize the importance of their part in accomplishing the maintenance responsibilities. Our industry is a high maintenance, high tonnage, and low profit type of industry and our efforts to reverse this to low maintenance high profit will certainly secure the approval of all our stockholders and bosses.

W. E. Schaffnit

TO the question "Will the cost of a good preventive maintenance program be justified when it produces a minimum of down time," the quick short answer is always YES. However, let us break this down and examine parts of the question. Just what do we mean by preventive maintenance? Quickly, it can be classified as good housekeeping, standard schedule for greasing and inspection, and replacement of parts before actual failure occurs.

Or consider "down time." This we assume to be the time equipment is out of service—naturally during the rush season—due to parts failure.

Too many plants do not have any definite schedule for either cleanup, greasing, or general inspection. A man is given a grease-gun and every morning he pumps the bearings full of grease until there is more on the outside than on the inside of the housing. Practically all machinery today is equipped with anti-friction bearings. The manufacturer gives a recommended type grease and the approximate time between applications. We venture to say that in 80% of the plants today, these charts are never consulted or followed. Too much grease is as bad as too little. This is particularly true in high speed equipment and in all bearings in cold weather. Too much grease in high speed equipment causes heat and in cold weather causes hard starting.

Now consider general good housekeeping and by this we mean cleaning up. This is one place where many hours can be saved in down time. Machines where dust and material has built up until the shaft and bearings are covered are surely asking for trouble but can give many additional hours of service if this dust is kept away. Dust from fertilizer material seems to have an uncanny way of working into bearings. A large part of this wear can be prevented by keeping dust away. The cost of one or two men's time with proper equipment can be saved many times if they will be put to doing a real job of cleaning.

To illustrate how this pays off —we know of a plant where a definite program of cleaning, painting, and greasing has been carried out and the small mixing and shipping unit is still in excellent condition after some 18 years.

Now consider inspection. Manufacturers in their instruction sheets furnished with equipment generally suggest that at least once a year, dust seals be removed, and the bearing and housing thoroughly flushed of the old grease. Clean the housing and repack. This is the time to carefully examine the inside of the housing, all dust seals and all parts of the bearing proper. If any parts show signs of wear this is the time to make replacement. The cost of a bearing is far less than a few hours or a day during the rush time should the unit go out. This practice applies to all bearings—elevators, mixers, screens, and mills.

Take the big item in fertilizer plants, namely elevator chain. We could discuss this pro and con as to when to change chain for many hours and still not reach a definite conclusion. We can state with a fair degree of accuracy that most plants allow a chain to run until it breaks and then don't have a spare in stock for quick replacement. It is suggested that a record should be kept of the date of installation and the approximate tonnage handled. Then when a chain has been operated close to this tonnage, closely spaced checks should be made on its condition.

Take another item—that of hammers in tailings mills. By closer periodic inspection, and it should only take a few minutes, many sets of hammers could be used for much longer periods befor replacement is required. Turn the ends before wear gets to the bolt holes.

Preventive maintenance, we know returns its cost many times no matter what a piece of equipment costs. Fertilizer plant machinery should have heavy rugged shafts and bearings and this, we believe should always be considered when making installations. This will reduce parts failures.

However, we believe that good housekeeping is one of the main points to stress and this is something every plant can take care of.

It is therefore suggested that every plant no matter how large or small can set up a program of:

1. Keeping the plant clean, particularly around equipment.
2. Set up a log sheet of lubrication.
3. Set up a log sheet of full data covering elevator chain.
4. Open all bearings, flush out and repack with the proper grease at fixed intervals. This can be based upon the manufacturer's recommendation as an instruction sheet generally is sent for each piece of machinery.

DISCUSSION

Monitor: A. Spillman.

Mr. Sam E. Shelby.

After hearing all these speeches this morning and this afternoon, particularly the one from DuPont in which he began several thousand of years ago and came up to 1958, I really wonder where we, in the production department in operating fertilizer plants stand today. Are we in 65,000 years ago in the Bronze Age, or are we up in 1958? I don't believe we're quite as far advanced as he might be in the program he outlined.

Briefly, I would like to first, kind of discuss a little bit with you preventive maintenance itself.

From an operational standpoint, I'd like to discuss some of the component human elements that make up a good preventive maintenance program. Number 1 is the operator, the driver of a piece of equipment, or the foreman, the person in charge of the operation of that equipment.

The one that was explained to us this morning by Mr. Jessen, from DuPont, was extremely broad and complete program, one somewhat similar used by the armed forces, it is very complete, it takes a lot of men to administer that type of program. We, in our company, do not have near the number of men that we could designate as maintenance men, as he spoke of this morning, but we can have a maintenance program that is tuned, repaired and used in our own organization.

We might analyze briefly where does a good maintenance program start. I strongly believe that a good maintenance program first starts in the minds of the men that are responsible for the operation of that plant or for the building of a new installation. And from there it then goes to, possible, a drawing board or a blueprint, in which good preventive maintenance is provided from the word go in the minds, the blueprints, the installation of the equipment, and the selection of equipment. I, for one, strongly believe that good equipment is the cheapest equipment in the process of making fertilizer. I try, as best I can in our company, to help select good equipment. I believe that in the long run, your capital investment might be greater, but after several years of breakdowns, expensive maintenance, that capital investment usually pays off if you eliminate some of those elements.

Then, the organization, the function of a good maintenance program within the organization, this all makes a good program. It doesn't have to have all the details, I don't believe, as the program explained it, but it does have to have a specific functional operational program with chain or command and responsibility. For example, a chain is no stronger than its weakest link, so we must have all of those links organized together in working toward a common goal of having a program that produces the least expense and the best operating efficiency.

We, even in our industry, can do a lot, I think in preventive maintenance even around our premises, around our factories, the cities in which we operate. Generally speaking, we are not as clean as some of our neighbors. We can do much toward that. I strongly advocate that.

Mr. W. E. Schaffnit comments.

And I might say in passing, that, and I think other equipment manufacturers will bear me out, when they get calls in cold weather, they can't start the equipment, the first thing we generally tell them is, open up the bearing and take two-thirds of the grease out and you'll start. This is particularly true in a northern climate.

Now, you might think we're stressing this, but people who get around to various plants can readily cite instance after instance where there's a foot of dirt around the equipment and this, we believe, you'll agree is not good practice.

(Applause.)

Monitor Spillman: Thanks to Messrs. Prosser, Shelby, and Schaffnit for the constructive answers on Question No. 2. I'm sure some of you folks in the audience may want to comment on this question. If so, we'd appreciate your comments.

I know maintenance in our plants worries most of us folks, and we all want to know what to do about them, so if there are any comments, let's have them. Harry Fader, are you here?

Mr. Fader: Yes.

Monitor Spillman: Harry, would you care to comment on some of the things that we do on replacement parts and how we handle our situation, for a second or two?

Mr. Harry Fader: We have to supply a part and would have to take a part out of the storeroom and order another part immediately to keep chains and sprockets and spare parts. Ours is a crane plant of special wired motors, we have to have to keep all these parts on hand. We have a schedule for cleaning every day in these operations where we work.

We try as much as we can on preventive maintenance to take care of things before they actually break down, but the supplies we do keep on hand. We've been at this plant since 1926 and I can only remember one time we were tied up by motor trouble. We had two motors to go up within a couple of days and we waited about eight hours until we got the first motor back, and that was during one terrible season.

The fertilizer plants are in buildings that are not exactly what they ought to be and run during one season. We do keep parts on hand. We have a pretty good schedule for cleaning up lubricants, we do that.

Monitor Spillman: I might say in our plants in Baltimore, we have approximately $30,000 worth of parts on hand, and as far as I'm concerned, I don't care whether we ever use those parts, but, boy, it's really good insurance. You can go home at night and go to sleep and know that if anything happens you've got a part to replace.

I see no difference in keeping an inventory of parts supply than paying premiums on insurance. We're protecting our men and we pay premiums year after year on fire insurance and all types of insurance ,and I think we ought to have at least those parts on hand that we know wear out from time to time.

There's an illustration here. About six months ago we had some difficulty with a rotor in our fan, and they're all special type equipment, but, by golly, we had a rotor on hand which had been there for about six months. And when we put the rotor in, we knew that we probably wouldn't need another rotor for six or eight months, but we ordered one immediately. The cost of the rotor was about $300, but it was the best insurance that we had. And that's where I think a good many of us can save on "down time," I call it, it's part of preventive maintenance.

Cleaning up is very important. A good many people come into our plant and say, "Well, you're operating eight hours a day and you're cleaning up for an hour and a half, so you're operating nine and a half hours a day." Well, they're right. But, by golly, I'm going to operate nine and a half hours a day and I'm going to spend an hour and a half in cleaning up, so that when we start out tomorrow morning at eight o'clock, we're ready to start. We don't lose two hours because the plant wasn't cleaned up or the equipment wasn't cleaned up.

I think you have to spend money to make money. You don't get anything for nothing. And I think the quicker we, in operation, do some of the things to help cut down on loss time in the end it will pay off.

I'd appreciate having any other comments about what we have talked about. It has helped the group. I think a good many of you are doing the things that I just talked about, and we'd like to have your comments. I think this is a very important question, it's a costly question. I know a good many plants are down day after day because the little things have not been done.

Mr. Melvin Leach (Indiana Farm Bureau): What do you do with that material you sweep up?

Monitor Spillman: Well, in cleaning up, you know, we talk a lot about cleaning up. Actually after you've cleaned up you can take all the material that you cleaned up, and I doubt it would average over a ton a day. What we do, we feed it back into the elevators or into the mixers during the day's work, a little at a time, and that's the only way to get rid of it, and it don't affect your analysis a bit.

Mr. George Reed (Webster Phosphate): I believe Mr. Shelby mentioned a stores inventory of approximately ten per cent of the plant investment. Now, is there any other discussion on that? That sounded a little high.

Monitor Spillman: Well, we'll take our plant in Baltimore. I told you we had an inventory of about $30,000 worth of supplies, and I would say our equipment cost us about—the original equipment investment in our Baltimore plant would go about $500,000. So, you're not too far—there's seven or eight per cent.

Now, the inventory supplies that I'm speaking of are parts that wear out and you can't just go to a machine outfit and say, "We want a special gear today." I would say the estimate at eight or ten, or even fifteen per cent on supplies, if they're needed, I still say they're the best insurance policy you have.

Are there any other comments on Question 2?

I think it's a very fine question; it's important, and I think that a good many of our plant operators are doing just those things that we're talking about.

Speaker, Mr. W. F. Campbell.

Monitor Spillman: What we're talking about in this particular question is corrosion, types of materials for piping and valves and belt conveyors, steel structure. Can we have an open discussion from the group; can we have anybody in the group to comment on that question?

What can we do to substitute some of the piping column steel mixers with other types of metals to hold down corrosion?

We have Mr. W. F. Campbell here in the group, who represents the Haynes Stellite Company, and if Mr. Campbell will give us a little background on what his company has to offer, we would appreciate any comments he'd like to give us.

Mr. Campbell, I don't like to put you on a spot; I think if you could give us a little information on the types of equipment or material that you have to offer that may hold down on corrosion, we'd appreciate it very much. I know you don't have any special talk, but anything that you might want to say in this respect will be helpful.

Mr. W. F. Campbell: Thank you very much for the opportunity to attend your Round Table. This is our first attendance at this sort of meeting.

We have recently become aware of the fact that various individual companies have had corrosion problems with piping, mainly, as I understand it, for sulphuric acid being fed into the ammoniators.

Our company is in the business of producing alloys, high alloys, mainly nickel and cobalt base and a few highly alloyed iron base materials. Actually, we produce over 100 alloys ranging in industry—practically any industry which we would care to consider, food, automotive, all industries, or applications involving items such as jets, missiles, on down to the dentures which some of you may have.

Specifically, for your industry, we have two nickel base materials, both of which are very good for severe corrosion where, we would say, we begin with our materials where the stainless steels and other more common and cheaper materials would fail prematurely.

Of the two—are we permitted to use brand names?

Monitor Spillman: Yes, you are.

Mr. Campbell: Of the two, Hastelloy C is recognized as being one of the most universally corrosion resistant materials, or alloys, available. This is a 54 nickel, 16 "moly," 15 chrome, and 4 tungsten composition. It is excellent for sulphuric and phosphoric acids at room temperatures, and for, I would say, up to a 150 degrees or so.

Another composition would be Hastelloy D which is much higher in nickel, 82 nickel, 9 silicon, and 3 copper. This composition is used mostly for high temperature applications ,such as concentrating sulphuric acid. It's good for all temperatures and all concentrations, including the boiling point.

There are some limitations that should be mentioned, so that you're not surprised if you're seeking a material and you find that maybe one material is not available in a form in which you want it. Hastelloy D is available only in the cast form. However, in the cast form, you can obtain pipe. It is not readily machinable; in fact, most of the operations would have to be performed by grinding.

Hastelloy C is available in cast form, wrought, forgings, and so on. You can, for instance, your distributor pipes, you can get wrought pipe, you can get cast fittings, you can get wire and foil down to 1,000 or 2,000ths in. thick for instrumentation. Your valve and pump people, or most of them, can offer hastelloy either trimmed valves and pumps and instrument components, or solid Hastelloy.

I'd like to mention one thing. We have some brochures in the back of the room which contain corrosion data. Now, we'd like it understood that the corrosion data which you will find is, unless it's otherwise noted, is for pure acids in glass. Now, we aren't gilding the lily with this presentation of corrosion data in that form. Obviously, it cannot be taken as the exact rate that you will get in your production plants. However, they will help you as a guide to select several materials which would, if you feel tests are required, enable you to select several, rather than running an indeterminate number.

We also have available through our company free corrosion samples. We also can furnish you with ASTM test procedures for corrosion testing. One thing that should be mentioned if you find that corrosion testing is desirable in your plant, would be to consider a test which would involve several months, if possible. In fact, some of the materials will show a decreasing corrosion rate over a period of three or four months, so if you can run your test for, say four to six months, you would come up with a more accurate figure.

We have also in the back of the room some blue cards such as this (indicating). Now, they're not addressed. On these cards, since we had no idea how many people would be here, and couldn't bring up much literature anyway probably, if you would designate corrosion resistant materials, we have others which would be of interest. One specifically, you folks have discussed bearings quite a bit here today. We have among our many alloys a series of cobalt base, which, in addition to being hard and wear-resistant, have extremely low coefficient of friction. As a matter of fact, on slow moving equipment, such as conveying equipment and agitators, if you have a problem with lubrication, you can run stellite on stellite dry even.

Now, I say, that is a qualified statement. You must have a sloppy fit, a high-speed pump. You cannot run stellite on stellite. The only thing I could suggest, if you have a problem where you have abrasives that are taking either your shafts or your bearings out prematurely, if you will let us know about it, we'd be happy to discuss them indivdually.

I think that I have had more than a couple of minutes. There are four of us here, incidentally, and if there are any individual questions afterwards, we'd be happy to talk with any of you.

Thank you.

(Mr. Campbell requested that the following remarks be included with the foregoing for clarification:)

Mr. Campbell: Hastelloy-D is limited in its machinability. Some machining operations can be performed, for instance, 50 per cent threads can be ground. For further information, please check our Hastelloy book which has complete instructions or contact one of the Haynes-Stellite representatives.

Monitor Spillman: Thank you, Mr. Campbell. It was very nice for you to come up and give us a little information on corrosive materials.

I recommend to all of you that you get one of those cards, and ask for the booklet Mr. Campbell talked about. I think it will be very interesting and helpful to you.

We're going to move along here for the time being, and we'll skip Question No. 4 and come back to it later if we have time, and go on Question No. 5.

Mr. Whitlock: May we have just another minute on this corrosion? Last year at this meeting we had a number of people comment on their successful use of Hastelloy Sparges. At that time, it was fairly new as a sparger material of construction, and several people voted 5,000 to 10,000 tons of material produced with Hastelloy C Sparger without any visible effects on larger whole size or corrosion or erosion.

Now, there are fellows in this room now who, I know, have up to 40,000 or 50,000 tons without any visible effects of corrosion or erosion, and I would like to hear some comments just briefly from several different people on the success that they've had during the past year.

Monitor Spillman: Well, thanks a lot. We, ourselves, have used the Hastelloy C type for both phosphoric acid and sulphuric acid. Harry, how old is that pipe now?

Mr. Harry Fader: It was installed the 20th of January, we started with 28,000 tons and it shows no sign of wear.

Monitor Spillman: It's really a nice piece of equipment for phosphoric acid and sulphuric acid, and believe me, you can save yourself a lot of headaches changing pipes every day like we used to when we had the old cast iron pipe.

Are there any other plant operators who would like to comment on the Hastelloy C or any type of pipes?

Mr. Melvin Leach (Indiana Farm Bureau): The action between the Hastelloy type that you use and the regular steel connection. Is there anything to that?

Monitor Spillman: The question, as far as we're concerned at our plant in Baltimore, we've had no such difficulty.

Mr. Campbell: I would like to have a comment on this, the several factors that would be involved in this, Mr. Norman Webb, of New York.

Mr. Norman Webb: As regards the catholic corrosion in any cathodic couple, cathodic material is corroded more rapidly than a non-cathodic material. In this case, steel is anodic in its rate of attack and will be highly accelerated. However, there is a ratio variant here. In a case of this kind the relative area exposed of steel, various Hastelloy C, were probably so high that the effect of Hastelloy C will be virtually negative.

Mr. Al. Henderson (Wilson Toomer Fertilizer Company): We have 40,000 tons of the Hastelloy C and I wish somebody would comment about the machining characteristics of Hastelloy C welding in a machine. It seems to be quite a problem.

Mr. Webb: Hastelloy C machines, unlike 300 series stainless steel. It is somewhat more difficult, but we are prepared to give you detailed machine settings for all the kinds of machining operations, and that's not a great drawback. The speeds are somewhat reduced, but it's not any serious problem so far as welding is concerned. It's a high order of material and we recommend welding with Hastelloy C welding rod for the welds to be made, and there is no particular difficulty here. There are many, many welders that know Hastelloy C and see no difference between that and welding stainless steel. These are all covered in the book on Hastelloy C as well. There's quite a bit of detail on this machining.

Question No. 4—Discuss Preventive Maintenance as Related to Fast Efficient Means for Cleaning Granulation Equipment Such as the Ammoniator, Drier, Chutes, Pulverizer and so on.

John Preston Crowder, Jr.

WE have no solution for this problem, but we are giving it some attention and can only offer suggestions as to the best methods.

The air or electric hammer with properly shaped bits is presently used. The bits are shaped to conform to the surface we are cleaning; scoop shaped bits used in the ammoniator and drier and flat bits in the chutes. The bits can be easily fabricated by the use of "Leco" hexagon tool steel available from Lehigh Steel Company. This steel is readily worked in the lathe and easily forged into the desirable bit shape and requires only water quenching to harden, no drawing is required. Bits can be fabricated at a fraction of purchase cost.

The motor driven electric hammer is the least desirable hammer in a fertilizer plant due to difficulties arising from short circuits.

The ideal solution to the cleaning problem would be a material that could be sprayed on the caked fertilizer deposits and cause it to sluff off with no manual effort being involved. There appears to be some promise in the use of oil-water emulsions as an aid in softening fertilizer deposits; certainly this reduces the cleaning time by half. Oil and kerosene soften the deposits but a more economical mixture is an oil-water emulsion.

There appears to be a real saving in cleaning time if the deposits are removed before excessive build-up occurs as the deposit is more readily penetrated by the oil-water emulsion and the deposits are much more friable.

Our present recommendations are:

1. Remove the deposits from the ammoniator and drier when deposits build up to ½" thickness, if possible.
2. At the end of the last run prior to cleaning, wet the fertilizer deposits while still warm with a 30-70 oil-water emulsion. Allow to sit overnight before chipping.

It is believed that an emulsion could be prepared that would cause the fertilizer deposits to slough off without chipping; however our work to date hasn't produced such a material.

The problem in V-C so far has been approached on pilot plant scale only and application to factory scale operations is planned if pilot plant methods of cleaning are successful.

Question No. 5—Discuss Economics of a Dust Collection Program Throughout A Fertilizer Plant, that is, Granulation System, Elevators and Shipping Mills.

F. A. Retzke

I SHALL discuss first our experience at one plant with a dust collection program for a granulation system. The system included a single-shell, rotary type dryer and cooler. The air volume through the 8-foot diameter, co-current dryer was about 21,000 cfm. The air volume through the 7.5-foot diameter, counter-current cooler was about 18,500 cfm. The solids throughput was approximately 25 tons per hour. Two, dry-type cyclones in parallel were installed initially on each unit.

Based on limited test results, 1710 pounds per hour of dust were collected, 440 pounds by the dryer collectors and 1270 pounds by the cooler collectors. For a conservative estimate, the dust was valued at $20 per ton (the cost of normal superphosphate which on a pound basis is one of the lowest-priced, conventional, plant food materials). Thus the value of the dust recovered would be $17.10 an hour. Based on a finished product rate of 20 tons per hour, this would convert to 85.5 cents per ton of finished product. For a plant producing 40,000 tons per year, this would equal $34,200 per year on an investment of about $15,000 for these collectors. That's not a bad return but it's only part of the story.

On a weight basis, these collectors were about 90% efficient, 84.2% for the dryer and 93.0% for the cooler. About 179 pounds per hour of dust escaped from them, 82.2 pounds from the dryer collectors and 96.5 pounds from the cooler collectors. This emission was a nuisance in the neighborhood and greater than permitted by the city air pollution code. To reduce the emission to one-half the code requirements, secondary collectors were installed on each system. Each unit contained four, high efficiency, dry-type cyclones in parallel. Since they had to be fitted into an existing system, the installed cost was about $35,000.

A performance check on these units indicated that they were collecting 117 pounds per hour of dust, 52.5 pounds from the dryer and 64.3 pounds from the cooler. Again at $20 a ton and at 40,000 tons a year, the return would be $2340 per year. This rate of return would not of itself justify the investment.

The dust escaping from these collectors was 62 pounds per hour, 29.7 pounds from the dryer and 32.2 pounds from the cooler. On the same cost basis as above, the present dust loss would be about $1240 per year.

At the time of installation of both the primary and secondary collectors, the big collector manufacturers we contacted were not ready for this problem. Today, a bag house could be installed to collect about all of the 1889 pounds an hour of dust escaping initially from our units, 522 pounds from the dryer and 1366 pounds from the cooler. A bag collector to handle 40,000 cfm would probably cost about $75,000. On the previous cost basis, this would yield a return of $37,740 per year. Only on the premise of handling all the dust, could one economically justify the cost of high efficiency collectors. As previously shown, less expensive equipment will do about 90% of the job. The value of the other 10% will not of itself pay for the relatively expensive equipment needed for the job.

At present I have no similar comparison for a dust collection program on elevators or shipping mills. Again a bag collector or a wet collector would, in my opinion, be required for efficient collection of this fine dust. The installed cost of a bag collector for this purpose would be about one dollar per cfm of air to be cleaned.

Other economic factors must be considered in evaluating a dust collection program, even though they do not appear as an item on the profit and loss statement. These include:

(1) Equipment maintenance is certainly reduced by some factor if there is less dust around the equipment.

(2) A worker should be more efficient, and possibly a better quality worker can be hired, if he can breathe clean air. For those who have unions to bargain with, here is an item which will appear sooner or later.

(3) To meet industrial health codes a company may have to adopt such a program to continue operations.

(4) Community relations will certainly be improved by a dust collection program. And again, as air pollution codes are tightened, a company may be required to clean up the air to stay in business.

W. E. Foote

AN answer to this question might well be found by looking to other industries, since dust control is not peculiar to the Fertilizer Industry, although the dust control problems of this industry do have some peculiar aspects.

Some industries, such as the milling, food processing, and many segments of chemical processing, to name a few, have long since recognized the feasibility of dust control.

This is not difficult to justify if we try to visualize for a moment the dollar expenditures resulting from *lack* of good control.

In a plant lacking good control, many of these dollars go up stacks in the form of *tons* of product. Many more dollars drift around inside the plant, where they eventually settle down on floors, stairways ,and equipment, where *more* dollars must be spent to clean them up as a good housekeeping or safety measure. Still more will find their way into places where they cannot be cleaned up, and remain there causing damage until even more dollars must be spent to repair that damage. I refer here to bearings, compressor cylinders, hydraulic cylinders, truck and vehicle engines, and electrical equipment and motors which are damaged by abrasion, or in some cases, corrosion. Some dollars will settle on plant roofs, where more dollars must be spent for removal because of the accumulated weight, or in some cases, fire hazard. Explosion hazards have moved many plants toward control measures. Still more dollars in the form of dust will drift over neighboring areas, where large dollar losses can be sustained due to civil action, or, as has been the case, shutdown of the plant on days when the wind blows in the wrong direction.

Employee efficiency, morale, and turnover have all shown marked improvement after the installation of good control measures.

These examples are drawn from industry in general, yet I think you will agree that most of them apply to your industry. Therefore, it is reasonable to assume that if control measures have paid off in other industries, they can and will in yours.

In considering the application of this assumption to your industry, it is well to bear in mind that each particle of dust has a source, and the easiest and most economical place to control that particle is at its source.

Dust control in a fertilizer plant should start at the phosphate rock mills. Ventilation is required at the feed and at the discharge. Control at these points will prevent material loss, reduce maintenance on surrounding equipment, and increase operating efficiency of the mills. Heat generated in the milling operation tends to make the extreme fines sticky, and they then will cause blinding of the screens, which follow as the next operation. Control of these fines at this source would certainly seem a wise act of preventative maintenance.

Conveyor belt transfer points are a common source of dust and should be controlled in order to fully realize several benefits, such as conservation of material, reduction of damage to surrounding equipment, and many of the other advantages previously stated.

Elevators fall into the same category, and should be properly ventilated according to cross-sectional area and height.

The mixing of rock and acid creates a dual problem, since dust from this process is corrosive. Here is real need for control as a preventative maintenance measure.

In the batcher, where dry materials are mixed, dust is of course created, and from here on in the process, the dust takes on a greater value, since it is no longer "just raw material." Good control is essential here, with prompt return of collected material to that particular batch of product. This will add quality control to the other advantages to be gained.

In the ammoniator, we again have both dust and fumes, and I know you will agree that ventilation is essential here, especially if you have been around an ammoniator unit when the air flow was interrupted for some reason. Again, the dust carried off in this ventilating air is valuable and should be collected for good economy.

Next in a granulation plant comes the dryer, felt by many to be the "Frankenstein's Monster" of the Industry insofar as dust and fume control are concerned. Dust is a double offender, due to its loss as almost finished product, and as a nuisance. The familiar "blue haze" is perhaps too fine to be called dust, but is nevertheless a very real part of this control problem. Due to variations in dryer operation, types of fuel used, and plant location, it is difficult to generalize on corrective measures. The amounts of material involved in this loss are considerable, and automatically demand recovery for efficient plant operation. The elimination of the "blue haze" is a must at most plant locations due to local regulations. The eventual answer may well be a dual stage system, one to recover the dust, the other to eliminate the fumes.

The cooler, while guilty of exhausting a quantity of dust equal to or greater than the dryer, is easier to control because of lower exhaust temperature, less moisture content and absence of "blue haze." Recovery of effluent solids is just as important for good economy as in the case of the dryer.

Shipping mills are a source of great material loss and operator efficiency improves with the advent of control measures.

From the foregoing then, we would gather that the answer to the subject question would be affirmative. I would add, however, that it can be affirmative *only* if extreme care is used in the selection of collection equipment. It must be emphasized that *no* make or type of collector offers a cure-all, due to differences in process equipment and its operation. What functions satisfactorily in one plant has failed in another, even within the same company. Thus, each dust control problem must be isolated at its source, and treated individually, with due regard to all conditions peculiar to that particular source.

Collection equipment must be proven, through testing, for each dust source.

Reputable collection equipment manufacturers have available, and will offer the use of, test units capable of handling large enough volumes to duplicate operating conditions; and will furnish technically trained personnel to assist in the installation and operation of these units. *This is the way to do the job!* The practice of purchasing hundreds of thousands of dollars worth of dust control equipment on the strength of its performance elsewhere is *dangerous* and has led to bitter disappointment and great monetary loss.

Conscientious sellers of collection equipment will *not* try to sell on the basis that "it worked somewhere else." Conscientious buyers will not buy on that basis. Equipment should prove capable of accomplishing both material recovery and preventative maintenance *without* creating new maintenance problems within itself.

In summary then, I feel we can say Dust Collecting Systems can and will pay in preventative maintenance and operation costs when the systems are chosen with careful regard to initial cost, proven ability on each problem, installation cost, and operating and maintenance cost of the system.

C. A. Hoffman

THE answer in a few simple words is "definitely yes!" We will, however, discuss the question in a more complete manner.

The problem of dust control is significant to each one of us, since dust control contributes directly to company profit. Company profit is a must if the company is to stay in business, and is improved by increasing sales or reducing expenses. We will here discuss the latter—reduction of expenses.

In the fertilizer industry, as well as any other industry, management recognizes that production results in two kinds of materials—salable products and waste products. Salable products are the source of profits, whereas waste products are a charge against production. The waste products are those which go up the stack or down the drain and in the majority of cases, these waste products, if collected, could be either directly re-used in the salable products, a direct gain in profits, or be indirect profit as uncontrolled waste products can increase maintenance and other costs.

The installation of well-engineered and efficient dust collection systems results in direct profits when the collected material is directly salable as product or by-product or can be reclaimed for future use. Dust collection systems add indirectly to profit since dust, if not collected, can cause:

1. Finished product contamination.
2. Increased maintenance and equipment breakdowns—additional parts costs, labor costs and downtime costs.
3. Poor visibility and thus increased lighting costs.
4. Increased plant housekeeping costs—cleaning, painting, etc.
5. Decreased employee morale and thus lower production and perhaps the expense of greater labor turnover.
6. Plant health hazards.
7. Plant explosion and fire hazards.
8. Air pollution or neighborhood complaints resulting in an expensive litigation.

Illustrations of some of the above points are as follows:

1. A fertilizer company in Iowa installed a cloth bag type dust collector for collection of dust from a granular fertilizer dryer operation. The dust collector collects approximately 1800 lbs. per hour and this reclaimed material has a normal value of $50 to $60 per ton.

   The particle size of dust collected by the Wheelabrator Orlon cloth bag-type dust collector on this fertilizer dryer application is such that 98.5% passes through 100 mesh (approximately 147 microns) and 82.1% passes through 325 mesh (approximately 43 microns). The amount of particles passing through 325 mesh indicates a large percentage of particles in the small micron range. To present to you some idea as to micron size efficiency of the Wheelabrator cloth-type dust collector, the following is noted—in the collection of smoke and fume from the Wheelabrator electric furnace applications, a size analysis of the dust collected showed 72% in the particle range of 0 to 5 microns. The efficiency of collection was 99% plus by weight.

This same company has two cloth collectors on their bagging and bulk loading stations, installed in early 1956. One of these handles 10,000 c.f.m., the other 13,000. Their installed cost was approximately $14,000. Significantly, they collect 2% of the total of all material sent to the bagging and bulk loading stations. All of this material is salvageable.

In Michigan, another fertilizer company notes that approximately 1200 lbs. of fertilizer per hour is collected by the cloth bag type dust collector on a 35-ton per hour granular fertilizer production unit.

2. Dust generated during machine shop operations in a large New Jersey chemical plant caused excessive erosion of machine surfaces on lathes, etc. The installation of a dust collector system for collection of dust from such operations as metallic spraying, grinding, etc., alleviated this problem.
3. The rotor in a multi-stage centrifugal compressor used as a blast furnace blower was worn out in a few years time by the dirt in the plant air. The dust laden air had actually uniformly "air washed" the backplate and blades of the rotor to such an extent that they were considered unsafe even though the rotors were still in dynamic balance. The spare parts cost for these rotors was seven times the cost of the original rotors. The installation of a Wheelabrator ultra-filter, that is the use of a cloth bag filter plus filter aid, to clean atmospheric air prior to use in this centrifugal compressor, would have greatly alleviated this wear problem.

   A major steel company is installing an ultra-filtration unit on this application. The steel industry has also recognized the value of filtered air for reducing maintenance in motor and control rooms and numerous installations have been made, the largest handling almost 1½ million cubic feet of air per minute.

   The efficiency of the Wheelabrator ultra-filter is unsurpassed in the field of air filtration. Our original installation was at a sewage treatment plant. Here atmospheric air had to be thoroughly cleaned to eliminate plugging of submerged diffuser plates used to aerate the sewage. Even at a dust loading of only 5 milligrams per 1000 cu. ft. and particles of micron and sub-micron size, the efficiency was 99.23% by weight as reported by the treatment plant engineers. On another unit used to clean plant air prior to discharge into a motor control room, the following test results were reported by the engineering department of a large steel company: These tests noted that not only did the weight efficiency approach 100%, but the efficiency by particle count method was as high as 99%. The particle count method of testing collection efficiencies is highly sensitive to both large and small particles and is the most difficult test to "pass" by a dust collector.
4. A California ceramic tile manufacturing company recently installed a cloth bag-type dust collector for collection of tile dust from dust producing manufacturing operations. This company collects as much as 8000 lbs. per day of dust which can be reprocessed and thus reclaimed. The reclaimed material results in a direct raw material savings of $2,500.00 per month.
5. A fertilizer company paid for an entire corn crop in a field adjacent to its plant. An inefficient cyclone-type dust collector on a fertilizer dryer allowed excessive dust concentrations to be discharged to the atmosphere with resultant chemical burning of the corn. This company has had no law suits since installation of an efficient cloth bag-type collector.

The above examples of problems of crop damage caused by air pollution shows that the problem of air pollution has become increasingly serious. It has a direct impact on the daily lives of the people, both in and around the plant. It affects people personally and intimately and so arouses strong, sometimes violent, public reaction. Trap the dust at its source by the installation of an efficient dust collection system and you will also eliminate the problem of air pollution many times at a profit.

Remember, too, the sphere of preventive maintenance and operating costs at the dust collector and the dust collector system itself must be kept in an effective operating condition by giving it the same kind of attention as is given to production equipment.

So once again, the answer to the question "Would a dust collection system pay in preventive maintenance and operating costs?" is still "definitely yes!"

DISCUSSION

Mr. Hoffman: I didn't mention any cost data for fertilizer drier applications. Actual cost for equipment including fans, the collector itself, controls, motors, V-belt drives, and so forth, on the installations we have, have run 80 cents per design cfm. Cfms. have ranged from 30,000 to 40,000 cfm, depending on the amount of tonnage throughput of your drier application.

We, of course, would not combine cooler air with the dryer air, and I'm sure Mr. Retzke did not infer that. I want to make sure you keep that clear in your minds, since we're handling a product that has a lot of water vapor in it, and we certainly don't want to cool it down by adding any cool outside air.

The dryer application would be an application in itself for a bag type collector. The cooler would be a separate, a distinctly separate application.

Design figure of a dollar per cfm is a good rule of thumb for any continuous automatic collector around 8,000 cfm, from our own experience. The higher you go, the lower the cost becomes. Therefore, I do say 80 cents per cfm for equipment to actually take care of the air from fertilizer dryer.

Of course to that, you have to add installation costs. We figure on the dryer a collector the size to handle a 38,000 cfm from a 35 ton per hour dryer, the installation cost would run around $6,000 at the installation. Now, the insulation costs would run, perhaps, another $6,000.

The temperature control equipment, perhaps, another $2,000. So if you add up all those figures for 38,000 cfm of air, the complete installed cost would be approximately $46,000.

Mr. L. V. Clegg (Canadian Industries, Ltd.) : You mentioned the figure of 1,200 pounds per hour. Now, under determination, how much of that would pass with cycle-over? How much of a turnover? You don't use cyclones.

Mr. Hoffman: No, sir, we don't. The cyclones as a primary cleaner is a moot point and has to be actually defined or has to be thoroughly looked at before you do say you need a cyclone or you don't need a cyclone. Just as Mr. Foote pointed out, there's no one type collector that is a panacea for all types of dust collection. In particular, when you do need a cyclone, is when the dust run is extremely high and you do have a good cross-section of microns, submicrons and much larger particles. If you have a preponderance of smaller particles, using a cyclone will take out the rocks, so to speak, and then you have all the finer material going to the bag collector, or another secondary collector, and that will give you increased resistance across the bag because of your finer particles.

Mr. Clegg: The answer to the other question. How much of a deposit dryer would you pick up after a cyclone. In other words, if you got the same thing.

Mr. Hoffman: I do know that they have cyclones on their fertilizer dryer. After the installation of the Wheelabrator bag house, we collected an additional ten per cent material. And that jibes very closely, I'm very happy to say, with what Mr. Retzke said, I believe 1,800 pounds, and he figured that if he had a bag collector he would collect 1,900 plus, it actually would be 1,980, I believe. We did find ten per cent, or the company found, the user company found ten per cent extra.

Mr. Glegg: Is that 180 pounds an hour?

Mr. Hoffman: That's correct.

Question No. 7—Discuss a Volume Displacement Meter Such as the Bowser Stainless Steel Meter for Handling Nitrogen Solution and Phosphoric Acid. Emphasize Economics.

W. E. Jones

IN the transformation of the fertilizer industry from a pure mixing operation to a chemical processing industry, one of the more difficult problems encountered was that of the flow measurement of various liquids employed in modern fertilizer technology. In this category also falls those compressible gases used which are metered as liquids. The more common of the materials referred to are the ammoniating solutions, anhydrous ammonia, various acids and water.

There are several types of metering devices available to make such measurements, some of which have been discussed in these "Round Table" meetings. One which has not been previously discussed is the positive displacement type meter about which I will briefly talk today.

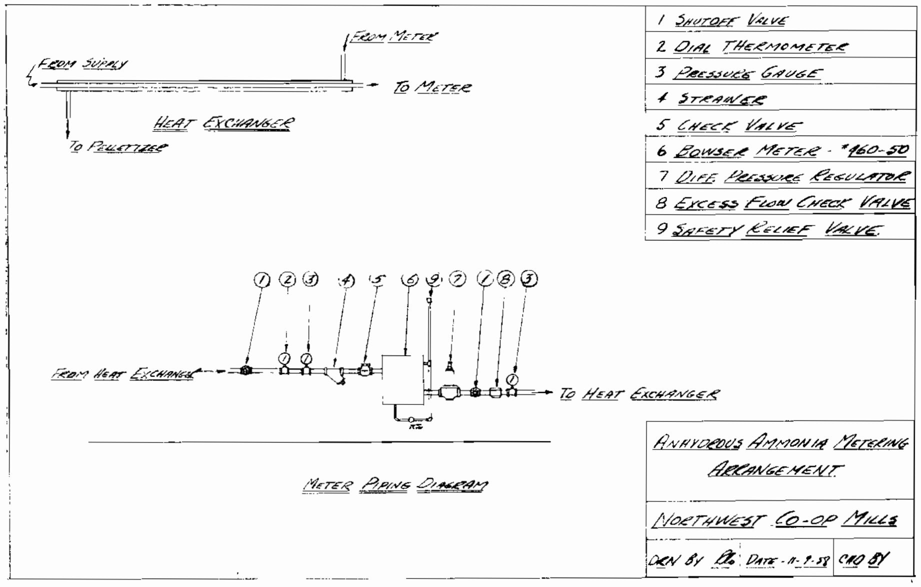
In its simplest form, the positive displacement meter would consist of a single unit of definite volume which would be alternately filled and emptied. A nonmechanical version would be somewhat like filling a container, such as a quart milk bottle, and then emptying it, keeping track of the aggregate total. Since this is not conducive to continuous processing, a meter such as the Bowser employs an arrangement of pistons wherein the total flow is an accumulation of measured increments which can be totalized by means of a simple counter. An indication of instantaneous rate of flow is available by adding a synchronized generator to the meter shaft having it power a volt meter which is calibrated in the desired units of flow. The details of construction of such a type of meter will be discussed in another paper on this program and I will not attempt it here.

The use of this type of meter has appealed to us because of the few variables which affect its metering accuracy and versatility. Basically, all that is needed to maintain accuracy is a specific gravity—temperature curve for the the material to be measured. In the piping to the meter a direct reading thermomoter can be inserted to supply the operator with the operating temperatures. The operator can be supplied a curve which will allow him to make the necessary operational corrections.

The meter can be calibrated with water into a weighed or measured receiver and the result plotted. This should be done at various rates of flow. If the plot does not fall in a straight line, it indicates the meter is out of calibration which can be corrected by a simple adjustment on the meter. This type of meter is equally accurate for all rates of flow which is the marked difference between this type and the area type meter, such as the rotameter whose measuring characteristics do not fall in a straight line and are therefore much more difficult to calibrate.

Thus far, we have used Bowser type positive displacement meters to measure flows on phosphoric acid and anhydrous ammonia. We have a good comparison of efficiency on anhydrous in that one of our operations employs rotameters and the other a positive type displacement type meter. The losses on the positive displacement type meter are over 30% less in essentially the same type operation. I have prepared a drawing of our anhydrous piping arrangement which is available for any so desiring.

During the 1957/58 fiscal year we metered in excess of 6,500 tons of wet process phosphoric acid through two Bowser meters and spent less than $10.00 for service, repair or calibration after the initial one. The meters were examined during last August and found to be in excellent condition. Our losses on this material were well within what we consider normal.



J. E. Doelling

ONE problem concerning the manufacture of commercial fertilizers is the measurement and dispensing of the basic chemicals in the manufacturing process. There are available today to the manufacturer various measuring and weighing devices, all designed to measure or dispense these basic chemicals into the manufacturing process. When you stop to consider the cost of these chemicals, the chemical and physical characteristics of these liquids, plus the need for accuracy in this operation, your choice of measuring equipment can be a very complex problem.

One device being used to a considerable extent in this field today is the positive displacement meter. It is a simple and economical item and the one we will discuss in this meeting.

Before going further, I think we should first define the term "positive displacement meter." Quite simply, any measuring device which, in effect, contains within its housing a measuring chamber that is momentarily isolated from the flow of liquid and which retains within this chamber a consistant volume of liquid for each cycle or cycles of operation may be considered a positive displacement meter.

There are many manufacturers of positive displacement meters varying in design and principle of operation, and each has their particular field of application along with their good and bad points.

I am sure that all of you, at some time or other, have heard of the rotary vane meter, the rotary swinging bucket, the oscillating piston, the oscillating disk, the reciprocating piston, or the vertical multiple-piston meter. Each, of course, are true positive displacement meters. The question . . . and quite often the problem . . . is to determine which is best adapted to handle the chemicals involved in the manufacture of liquid fertilizer.

In order to make a choice, we must first set down a certain set of requirements against the available types of meters. They are:

1. Accuracy
2. Durability
3. Compatibility with product being handled
4. Serviceability
5. Cost

Now that we have established these requirements, let's investigate each requirement and determine the physical design necessary within the meter in order to meet these requirements.

No. 1—Accuracy

Accuracy in any positive displacement meter means that the meter must be consistent in measurement over a given flow range and volume irrespective of pressure variations or viscosity changes of the product being handled. To do this, the following physical characteristics must be embodied in the meter itself.

(A) Since the measuring chamber of the positive displacement meter is a moving element, certain clearances must be provided to maintain operation. These clearances, in order to obtain accuracy, must be limited to the smallest possible area and the closest possible fit.

(B) The actuating members within the meter isolating the measurement chamber must be so designed as to be consistent with each revolution or cycle of operation of the meter.

(C) Also, the working parts within the measuring chamber must be so designated as to provide concentricity for each cycle of operation or multiple cycles of operation.

(D) In order to compensate for wear and manufacturing tolerances, an adjustment must be available to vary either the size of the measuring chamber or to change the relationship between the speed of the meter shaft in reference to the totalizing mechanism.

No. 2—Durability

The working parts within the measuring chamber must be durable and provide continuous operation without affecting the measurement of the meter over extended periods. In order to do this, there must be a certain compatability between the working parts that will be unaffected by the product being handled or the loads exerted upon them. The working mechanism also should be of sufficient durability to withstand continuous operation with little need for adjustment to compensate for wear and unaffected due to non-lubricating qualities of the product.

No. 3 — Compatibility With The Product Being Handled

In order for the meter to be compatible with the product being handled, it must be constructed of the proper metals that are unaffected by the products. More important is that these materials, working together, are mechanically correct and will not tend to gall, sieze, or wear rapidly due to lack of lubrication of the product. Good design in any positive displacement meter provides metals that are compatible with the product and yet compatible as a mechanical device.

No. 4—Serviceability

(A) In order for a positive displacement meter to be serviceable, it must be simple in design with the minimum number of working parts within the measuring chamber.

(B) In case of necessary service, the meter should be so designed that it is necessary to replace only a limited lumber of parts in order to place the meter back in operation and provide accurate measurement.

(C) Access to the meter for service should be simple and adjustment after service should also be simple.

(D) Availability of factory-trained service personnel in your area must be considered if you are to avoid any costly delays.

No. 5—Cost

Of the various types of measuring devices available for the measurement of liquids, the positive displacement meter is the least in cost at present. There is, however, a considerable difference in the prices of positive displacement meters. Before you consider the cheapest meter available for this application, you must first consider the various requirements necessary above and then select that meter that meets those requirements at the least cost.

We have now established a set of rules in the selection of a metering device for liquid measurement. Once made, it is only necessary to properly install this device in your plant.

The installation of this meter too is important as there are certain physical situations in its operation that will affect the meter's accuracy and performance if they are not also taken into consideration.

(1) All positive displacement meters, because of their design, will measure vapor and air. Therefore, a means must be provided to eliminate the vapor or air from the liquid prior to the measurement of the liquid through the meter. This can be done by the installation of a commercial air eliminator installed ahead of the meter, or by the means of a recirculating line mounted on the inlet of the meter back to the storage tank so that the vapors are returned to storage. Recirculation of the fluid through this recirculating line can be controlled through the means of an orifice.

(2) Every meter is designed for a maximum capacity in gallons per minute. Therefore, a means should be provided to control the flow through the meter so as not to exceed its maximum rate of capacity.

(3) In order to maintain consistent accuracy, the operation of the meter should be consistent in its starting and stopping operation. For instance, if a discharge line is installed on the meter in such a way that the line will be drained after each operation, this would tend to give you inconsistent measurement. A means should be provided so that this discharge line is kept full at all times; and this can simply be done by the means of a spring-loaded check valve or a positive type valve either automatically or manually operated on the discharge line.

(4) Foreign matter and abrasive material can do considerable damage to the meter. Fine abrasive material will accelerate wear and even larger foreign material can damage the meter to the extent of putting it out of operation. All positive displacement meters are dependent on close clearances; and any foreign material or abrasive particles must be removed from the liquid being measured before it enters the meter inlet. This can be accomplished by the means of a fine mesh strainer or, if necessary, a fine filter.

(5) Also, to provide consistent measurement and to limit service requirements on any positive displacement meter, a maintenance routine should be established. Most of this maintenance involves the counter mechanism which should be periodically cleaned of dirt and dust and lubricated to provide continuous operation. Occasionally, a meter should be checked volumetrically and adjusted if necessary to compensate for wear.

I am sure that if all these points are considered by the manufacturer, his choice in equipment should be simplified and the cost of the equipment involved will be at a minimum. He will obtain the best possible accuracy and require the least amount of service on his equipment in his plant operation.

Question No. 8—How Do You Calculate Area-Type Flow Meter Correction Factors for a Change of Specific Gravity?

Albert Beehler

PRACTICALLY all of you in this room, at one time or another, have had occasion to correct an Area Type Flowmeter or Rotameter for changes in the specific gravity of the fluid being measured.

This usually is desirable where a variety of ammoniating solutions and acids is used. A few of you were probably puzzled enough to call your local sales engineer, who willingly gave you correction factor over the telephone, but most of you, I would be willing to venture, calculated this correction factor yourselves by taking the ratio of the new specific gravity divided by the old specific gravity. You were then puzzled to find the resultant flowmeter settings did not produce a good analysis on your next run. My purpose in being here this morning is to show you why this type of correction did not produce the desired results and to provide information which will allow you to accurately calculate these factors when desired.

In the variable-area meter, you certainly all know that the free float is actually immersed in the flowing fluid. It is the resolution of the downward force created by the float weight minus the buoyant effect of the fluid pushing upward and the upward force created by the velocity of the moving fluid that actually positions the float to a specific position in the tube proportional to flowrate. Thus, a change in fluid density without any change in flowrate will cause a repositioning of the float because our buoyant force has been altered. For convenience, correction factor may be expressed as follows:

$$W_1 = W_2 \sqrt{\frac{(P_f - P_1)\ P_1}{(P_f - P_2)\ P_2}}$$

W_1 = new flow rate (in weight units) (actual)

W_2 = old flow rate (in weight units) (indicated)

P_f = float density (grams per cubic centimeter)

P_1 = new fluid density (grams per cubic centimeter)

P_2 = old fluid density (grams per cubic centimeter)

Substituting some numbers in this formula, let's assume for a moment that we have a meter with direct reading scale, maximum 5,000 PPH of ammonia solution, whose specific gravity was 1.06 and we have decided that for this particular run, we are going to use a solution, whose specific gravity is 1.14—then the correction factor would be 1.03—

$$W_1 = W_2 \sqrt{\frac{(P_f - P_1)\ P_1}{(P_f - P_2)\ P_2}}$$

$$\text{or } W_1 = 5{,}000\text{PPH} \sqrt{\frac{(8.02-1.14)\ 1.14}{(8.02-1.06)\ 1.06}}$$

$$W_1 = 5000 \times 1.03$$

$$W_1 = 5150 \text{ PPH}$$

thus, the 5,000 PPH setting on the flowmeter would be equivalent to 5,150 PPH of the heavier solution.

It is important here that this formula for correction be used only for variable area type meters of the free float type. On occasion, it will be necessary for corrections to be made to another type of flowmeter, namely, the magnetic one on wet process phosphoric acid service. In this obstructionless type meter, there is no float in the moving fluid stream, and therefore, the correction factor is merely the ratio of the specific gravity in direct relationship. This is a quite common correction, since all magnetic meters are true velocity meters measuring volume, and in order to put the calculation on a weight basis you must know your average specific gravity of the phosphoric acid during the period in question.

It has been my company's practice on solution and acid flowmeters and controllers to provide the meter scale direct reading in PPH of liquid, specific gravity 1.0 with suitable correction factors stamped on a metal tag on the instrument door for all of the various solutions which might be used. Thus, the necessity for figuring these correction factors has been reduced to the bare minimum.

If you have any questions regarding this subject, I'll be more than glad to attempt an answer in the remaining allotted time.

DISCUSSION

Mr. Suderman: Was the man's experience with filter wet process asked, and if so, what problems did he encounter with scaling? The fact was mentioned that close flow line tolerances were necessary, and how are they compatible to measurements, and what are their assets?

Mr. Beehler: Well, to answer your question, I think I'd like to call on Mr. Jones to elaborate a little bit, if he's still here yet, about his process of handling wet phosphoric acid with this particular meter. Mr. Jones, are you here.

Mr. W. E. Jones: Actually, in our experience, we've had no problem because it would appear, at least from the meters that we have, that we have sustained no serious wear from any suspended solids in the acid. Secondly, we've noticed no significant adherence of the solids, or any new build-up in the chamber of the meter itself. So actually, we have sustained no problem to date.

I can't say that that may not occur in the future, but so far it hasn't been a problem with us at all.

Monitor Spillman: Mr. Doelling.

Mr. Doelling: We have recommended in most cases for this application, that in installing the meter that they put in circulation lines, so that the meter used can be flushed with water. If there is any crystal formation it can be flushed out and the meter maintained with water until it's ready for the following day's operation, or whatever it might be. Does that answer your question?

Mr. Dwight Sanders (Swift & Company): I have another question about this displacement meter.

Monitor Spillman: We'll be very happy to have you give it.

Mr. Sanders: Reference was made to anhydrous ammonia with the positive displacement meter by one of the speakers, I don't know which. I would like to know how you handle the vapor problem.

Mr. Doelling: The question was, how do we handle the vapor problem in connection with the positive displacement measurement of anhydrous ammonia. Actually, Mr. Jones touched on that subject. I was talking basically about positive displacement meters.

I can tell you this. I mentioned in my talk that one way to cause an error in your metering would be through the measurement of the gases or the air that might be entrained in the liquid. And the way we do this—actually the meter that we're normally using for these anhydrous ammonia applications, is also a meter we use for liquid petroleum gases, it's the same meter. In that case, we connect to the inlet side of the meter a line back to the storage tank, in which we control the volume of flow through an orifice back to the storage tank, in which the top chamber of the meter is designed in such a way that we trap those gases that come in the meter and dispense them back through this circulating line to the storage tank.

Now, the case of Mr. Jones in his application, I believe that in his diagram showing the application of this meter on anhydrous ammonia, it will pretty well explain itself in that, in his case, he is taking the anhydrous ammonia on the discharge side of the meter, running it back through a—what is it, a condensing—beg Pardon?

Mr. Jones: We find that the discharge from the meter into the discharge cools the incoming stream before it's metered, and this, if not eliminating it, certainly minimizes the separation of the liquid and the gas. And in addition, we have a pressure control valve on the discharge side of the meter to keep the meter under a minimum pressure at all times, and we have no flushing problem in the whole diagram of our complete devicing setup, the meter, the heat exchanger and everything.

Mr. Doelling: Does that answer your question?

Mr. Sanders: Yes.

Question No. 9—What Is a Good Method of Adhering Teflon to Metal?

W. E. Jones

DUE to its unique non-adhesive surface, "Teflon" TFE-fluorocarbon resins cannot be bonded to other materials with appreciable strength by conventional means, although pressure-sensitive adhesives are used directly and found adequate for some purposes. Various manufacturers have patented techniques for treating or coating surfaces of "Teflon" to make them receptive to adhesive bonding. After such treatment, many conventional adhesives can be used and highly satisfactory bonds can be attained.

The methods for preparing the surfaces of "Teflon" for bonding are generally quite different from one another. Also, in general, they cannot be done in the field. Some of the processors who have patents on this subject are:

Connecticut Hard Rubber Co.
400 East Street
New Haven 9, Connecticut

Garlock Manufacturing Co.
U. S. Gasket Division
600 N. 10th Street
Camden, New Jersey

E. I. du Pont de Nemours & Company, Inc.
Fabrics & Finishes Dept.
Wilmington 98, Delaware

Minnesota Mining & Manufacturing Co.
Saint Paul, Minnesota

Question No. 10—A Discussion of Instrument Developments for the Fertilizer Industry.

W. I. Strauss

ONE of the most recent contributions to instrumentation of fertilizer plants has been the magnetic flow meter for measurement and control of phosphoric acid, phosphate slurries, nitrogen solution and sulphuric acid. This instrument has afforded fertilizer manufacturers more precise control of their product, thereby preventing costly over-formulation.

At last year's Round Table the principle of the operation of the meter was discussed and, therefore, these details will not be discussed at this time.

Some new advances in the art of flow measurement have been made this past year. The full scale minimum flow velocity has been decreased to one-half the previous requirement of 5 feet per second. It is now 2.5 per second. What this means to you is that for a 1″ metering tube the full scale value of 10 gpm has been reduced to 5 gpm. On the one-half inch size the full scale is now 1½ gpm instead of 3 gpm. Even though the velocity requirements have been reduced, the same $\pm 1\%$ system accuracy is maintained.

Along these same lines, two new sizes have been added. A three-sixteenth inch size with minimum full scale of 0.25 gpm and a one-tenth inch size with a minimum full scale of .1 gpm. It should be pointed out ,however, that there is no upper limit of flow. In other words, if the system can handle flow rates in excess of the minimum values the meter will accurately measure this rate. The one-tenth inch size would be applicable to pilot plant operations and laboratories, while the three-sixteenth inch size could be used in smaller plants.

A range change can now be made simply by adjusting the range potentiometer under the back cover of the Dynalog instrument. The range panel has room for two potentiometers with a selector switch conveniently located on the shield plate, making the instrument easily converted to two different ranges. Many users run different formulations and would have flow rates of phosphoric acid—in one case a maximum of 3 gpm and in the other a maximum of 30 gpm. Since accuracy is dependent upon full scale value, a range selector switch of this type would be extremely advantageous.

In the manufacturing process of the metering transmitter the Teflon insulating lining is now one piece of the extruded type with no need to bond Teflon material, thereby eliminating this problem and allowing the tube to be steamed out for cleaning.

Since almost all plants prefer pound units over gallon units, the chart may easily be calibrated in pounds where the specific gravity of the flowing liquid is constant. A periodic check of the specific gravity changes periodically, a vernier dial may be added to the instrument calibrated in specific gravity. After each check on specific gravity is made, the dial is adjusted to the new valve. The instrument then automatically corrects for the specific gravity change, saving calculation time. The device is most useful when several liquids of definite gravities will be measured by one instrument. If the process is such that the meter can, for example, first measure phosphoric acid and then measure sulfuric acid or nitrogen solution, the gravity adjustment for these materials is made on the dial and the chart will read in pounds of flowing material.

A flow totalizer or intergrator may be added to the Dynalog instrument to continuously indicate the number of gallons or pounds of liquid flow. For batch operations, a switch may be added to stop the process at predetermined quantity.

More than one metering transmitter may be used with the Dynalog instrument. A switch may be added to the instrument to provide switching of up to six transmitters on one recording instrument.

Another application where the magnetic flow meter has been successfully used is the continuous measurement of mass flow. This is particularly advantageous for the measurement of phosphate rock slurries where the flowing fluid contains enough rock particles to make metering any other way virtually impossible. A gamma radiation device—similar to those made by Industrial Nucleonics, the Ohmart Corporation and others—measures the density of the flowing mass, the magnetic flow meter measures the volume rate of the flowing mass and when multiplied together automatically in a multiplying instrument mass flow is obtained.

Instrumentation is a valuable tool available to the fertilizer industry. The benefits obtained are no less important than an improved dryer or a better granulator. There are many applications for instruments in this industry that have not been investigated thoroughly. Moisture control of product, ratio control of liquid feed to solids, and air flow control are some of these. The benefits of improved product quality through accurate formulation and consistent granule sizes are both economical for the user as well as the manufacturer. User benefits alone will reap increased sales for the manufacturers.

DISCUSSION

Monitor Spillman: We have a few minutes for some some discussion on this topic before we adjourn. Are there any questions?

Question: Is it necessary to make a gravity correction when you're measuring the volume by volume as to gallons per minute?

Mr. Strauss: Yes, because gravity is dependent upon the temperature. If your temperature is constant, then the gravity should stay constant.

Question: That is with respect to the same?

Mr. Strauss: Yes.

Thursday, November 6

Principles of Processing Economics

George F. Sachsel

History and Definition

PROCESSING has come into full flower in the twentieth century and is one of the characteristic features of what we fondly describe as Western Civilization. Fewer and fewer of nature's products are consumed by man in their original state, the changes they go through before they reach the consumer are getting more complex, and the operations for effecting these changes are getting more mechanized every day. Processing has become one of the major activities of Western Man and the people engaged in it are daily growing in number and importance.

Processing means change, either physical or chemical, or both. It requires the application of energy to raw materials to produce products that differ in properties and appearance from the raw materials. The outstanding characteristic of modern processing is that only a minute part of the energy required is supplied directly by human labor. Even the most primitive operation involves many things besides the cost of human labor. The simple process of cutting tree logs into fire wood involves tools such as horses, saws, axes, which require maintenance and repair, and ultimately must be replaced.

Cost Factors

Modern processing cost consists of a large number of items. How many depends primarily on the accountant who sets up the cost system. This discussion restricts itself to some of the elements shown in Table 1. These elements make up about 5 per cent of the total cost in a conventional fertilizer plant as shown in Figure 1.

Why bother about such a small fraction of total cost? There are several reasons for this: (1) As indicated by the examples of Figures 2 and 3, processing costs are likely to represent a larger portion of the total in the future; (2) These same figures suggest that one way of reducing raw material costs is to increase some elements of processing cost; (3) Whereas it is possible to adjust raw material purchases to sales, many of the elements of processing cost cannot be adjusted as readily. Depreciation, property taxes, interest and insurance continue unabated whether the plant is producing or not. It is no longer feasible to hire and fire labor in exact proportion to sales or output, partly because of our changing social attitude and partly because modern processing often dictates the same labor requirement for a plant whether it operates at 50 or 100 per cent of design capacity. Maintenance expenses may actually increase with decreasing output.

What is the magnitude of some of these processing cost elements? Table 2 shows a few direct labor figures for some processes that are either part of the fertilizer industry or closely related to it. About a sevenfold range in man-hours per ton is encompassed by the data. Attempts have been made to correlate labor requirements with the number of processing steps, but most of the examples have been picked from all-liquid-processing plants and it remains to be seen whether any generalizations can be made for fertilizer plants which handle both solids and liquids. Theories have also been proposed which state that labor cost represents a constant fraction of total cost in process industry but the examples cited have covered only a few selected industries.

Power data for some of the same processes are shown in Table 3 and these costs vary a great deal more than labor costs on a per-ton-basis as the 170-fold range indicates. To some extent power consumption is an index of so-called fixed charges since there is some correlation between power consumption and fixed capital.

As Table 4 indicates depreciation can vary but allowable rates don't often go above 10 per cent unless severe wear can be proven or rapid-write-off certificates can be obtained. Fixed charges are a reminder that it is not enough to make a nice profit on the sales dollar—the return on the investment must also be attractive or it will be hard to find capital in the future.

Principles

What then are the principles of processing economics, or are there any? There is probably only one really good general principle: any processing operation should yield a return on investment that is at least commensurate with the risk. What determines the risk? Why, the people to whom you go for equity capital, or from whom you borrow money. If interest on mortgages runs 5 per cent, equity capital must be promised a greater return on dividends or a promise of capital gain.

How does one apply such a general principle to the many steps and problems in a plant? By subjecting each operation to the economic magnifying glass and appraising changes in terms of capital need, power consumption, labor requirements for operation and maintenance, maintenance material requirements, to name a few major cost factors. Methods for doing this with relatively simple mathematics have been published in many textbooks and articles in the last 10 years.

One point that has so far been ignored in this discussion is the so-called break-even point which defines at what per cent of design capacity a plant operation goes from profit to loss. Obviously a plant with high fixed charges reaches this point sooner during declining sales than a plant with low fixed charges. This gets us into more general economics and market analysis, a subject outside the scope of this Round-Table session.

This rather brief outline of some factors in processing economics has probably presented relatively little new information. Its purpose was more to outline a way of looking at things and to stimulate discussion. If it does the latter, it will have been successful.

Table 1. Some Elements of Processing Cost

LABOR	Direct
	Maintenance
	Supervisory
UTILITIES	Fuel
	Steam
	Water
	Electricity
SUPPLIES	Operating
	Maintenance
CAPITAL	Depreciation
	Interest
	Property Taxes
	Insurance

Table 2. Some Process Labor Data

Process	Direct Operating Labor, Man-Hours Per Ton	Dollars Per Ton ($1.75 Per Man-Hour)
Superphosphate	0.60	1.05
Furnace Phosphoric Acid	0.80	1.40
Nitric Acid	1.00	1.75
Dorr Phosphoric Acid	1.7	3.0
KCl ex Sylvinite	4.3	7.5

Table 3. Some Process Power Data

Process	Electrical Energy Consumption, kwhr per pound product	Power Cost, Dollars per Ton ($.01 per kwhr)
Superphosphate	0.011	0.22
KCl ex Sylvinite	0.025	0.50
Dorr Phosphoric Acid	0.053	1.06
Nitric Acid	0.19	3.8
Ammonia	0.75	15.
Furnace Phosphoric Acid	1.9	38.

Table 4. Some Depreciation Periods For Chemical Process Equipment

Type	Years
Burners, sulfur	10
Conveyors, belt	15
Dust collectors	15
Packing machinery	15-20
Pulverizers	12
Pumps	10-20
Storage, acid	12-20

Question No. 2 — What is the Possibility of Drying at a Lower Temperature and Increasing the Retention Time in a Gas Fired Dryer? What Cost Advantage Would This Practice Develop Relative to Fuel and Electrical Cost Per Ton?

W. G. Mautner

FIRST of all the phrase drying at a lower temperature can refer to material or air temperature. Assuming that lower temperature refers to the product being dried, the following advantages would be gained by lower temperatures and increased retention time.

1. Avoid overheating of product
2. Decreased smoke and fumes
3. Minimum nitrogen loss during drying

To dry at a lower temperature requires more air through the dryer which means more horsepower on the fans. The dryer shell would be longer and require more power. This increased retention time could be done by a longer dryer, retaining rings in dryer and reducing RPM of dryer.

It is believed that low temperature drying of fertilizer would increase both fuel and electrical power costs and also capital investment in drying equipment.

How Can a Furnace be Designed to Reduce the Potential for Formation of Fumes Due to Over-Heating Fertilizer Granules?

G. Lang

THIS is best explained by the comparison of two examples: Assume a 20 TPH granular fertilizer plant with a 1 to 1 recycle.

The material will enter the dryer at 12% moisture and 130 degrees F. and discharge from the dryer at 1½% moisture. The material will discharge from the dryer at approximately 220 degrees F. and the exhaust gases will exit at approximately 270 degrees F. in both cases:

This will mean approximately 8500 lb./hr. moisture is to be removed and it will require 11.5 million BTU/hr. *net* heat input to the dryer to do this evaporating job.

Now with what we consider the maximum desirable dryer inlet air temperature of 1000 degrees F. for parallel flow drying and the previously mentioned 270 degrees F. dryer exhaust gas temperature we require 20,000 cfm of air measured at 270 degrees F. This is the net amount of air to do the best conveying job.

The dryer radiation loss under these conditions would be 1,130,000 BTU/hr. and the stack loss would be 3,150,000 BTU/hr.

This results in a gross dryer heat input of 15.7 million BTU/hr.

The fan to exhaust the drying air and moisture vapors would require a 50 hp. motor. Actually drawing approximately 42 hp. The rotary dryer would require a 30 hp motor. Actually drawing approximately 23 hp.

Let's assume we wish to do the same drying job with a 700 degree F. dryer inlet air temperature. The net drying heat requirement would be the same since the same amount of moisture is being evaporated and the fertilizer and exhaust gases are existing at the same temperatures. We would require now, however, 34,000 cfm at 270 degrees F. The net amount of air to do this heat conveying job. The dryer radiation loss under these new conditions would be 830,000 BTU/hr. and the stack loss now would be 5,350,000 BTU/-hr.

This results in a gross dryer heat input of 17.6 million BTU/hr.

A fan, three sizes larger than previously would be required and a 60 hp. motor would be necessary to drive it. Actually drawing approximately 58 hp.

The rotary dryer would require a 40 hp. motor. Actually drawing approximately 36 hp.

Summarizing we find an increase of 1.9 million BTU/hr. or 1,900 cfh of an average natural gas or 13.5 gph of fuel, an increase of 13 actual dryer h.p., an increase of 3 fan sizes with an increase of 16 actual fan h.p.; and with the most costly increase being in the larger dust collecting equipment that is required.

The larger equipment, with the exception of dust collecting equipment, would cost approximately an additional $3,000.00 and the increased utility cost would be approximately (10) cents per ton of product.

Particles which travel through the feed chute and the dryer in normal time contribute very little to the fume generation problem. These particles as in the two cases mentioned are not expected to reach a body temperature of over 220 degrees F., which is necessary to reach the desired moisture removal in practical production. On the other hand particles which stay permanently or for a considerable length of time on feed chutes and dryer feed flights and are eventually raised to near 700 degrees F., the latter of the two previous cases, will generate all the fumes that particles raised to near 1000 degrees F. will generate.

In simple tests at our plant in a closed room—small samples of an average grade granular fertilizer were brought to varying body temperatures starting at 200 degrees F. From 200 degrees F. to 300 degrees F. no appreciable amount of smoke was generated; however, at 300 degrees F. and above increasingly greater amounts of smoke were generated. Another small sample was held about a foot over an electric hot plate and in a very short period of time, before the average body temperature had reached 200 degrees F., the particles facing the radiant heat were producing a terrific amount of smoke. This heavy smoking fell off rapidly after the hot plate was turned off and the radiant glow left the element.

This simple experiment and our experience in the field proves the need for an answer to the third question "How can a furnace be designed to reduce the potential for formation of fumes due to overheating of fertilizer granules." The one basic answer, which isn't always easy to accomplish is to design a combustion chamber and burner system which produces as little luminous radiant heat as possible in both the flame and the refractories, and design the furnace so that whatever luminous heat source there is, that this source cannot "see" surfaces that convey material or material itself which is slowed in its travel through the dryer by sticking. This again is not always the easiest thing to accomplish.

I would like to cite our own experience as an example of the economic and operational value of practically eliminating luminous radiant heat.

One of our products is a gas-fired, air-cooled furnace which uses no refractories or insulation whatsoever. Refractories are the greatest source of luminous radiant heat.

The burners are of a type which break down the conventional large yellow ball of fire into many small blue, almost transparent, flames ranging from 6″ long up to 30″ long for 30 million BTU an hour furnaces. Luminous flames are second only to refractories as a source of radiant heat.

Surface temperatures on the outer-surface of the combustion chamber's inner shell don't exceed 500 degrees F. at maximum fire with correspondingly maximum air throughput.

In the last three years' production of these furnaces we have not used anything but 3/8″ thick carbon steel feed chutes and all of these original feed chutes are still in operation. Which to us by comparison with the life and chute design necessary in refractory lined furnaces is conclusive proof of the extremely abusive nature of luminous radiant heat.

Concluding, it is evident that lowering the dryer inlet air temperature some 200 to 300 degrees F. below an optimum of 1000 degrees F., with no regard for the radiant heat output of the furnace, would give no noticeable fume generation reduction. Lowering the inlet air temperature below this, we question whether it would be economically feasible.

From an economic and operational standpoint the effort to improve fume conditions should be put into the design of the furnace. This would not require any increased continuing utility cost as in the cost of the lower inlet air temperature. In the case of the gas-fired furnaces without refractories the overall furnace and burner cost is less than the conventional refractory lined furnace, and in the case of oil fired furnaces the cost of multiple burners to provide smaller shorter flames may be neglible.

Since the combustion of oil is not as satisfactory as gas in the absence of hot refractories, the conventional refractory lined furnace is still the most satisfactory. It should be sufficiently large in volume and the drying air should flow uniformly distributed across the furnace cross-section. All of this air should travel the full length of the furnace and the hot gases, where the dryer is large enough in diameter, should enter the dryer through a beeching where these gases would not envelope the material feed chute.

Question No. 3—Is the Use of Steam Economical In Achieving Granulation?

T. J. Bosman

WHEN we first started using steam it wasn't a question of economics, it was just plain necessity if we wanted granulation in certain formulas. We all knew 1-4-4 ratios were hard to granulate. At times 1-2-2 ratios caused trouble.

In certain sections where we do business 4-16-16 and 5-20-20 account for considerable tonnage. Early in 1955 the demand for these grades in a granulated form was becoming so strong, we could not ignore it any longer. We had been trying to granulate these grades, but had only made a semi-granulated goods. We knew something had to be done.

It was known granulation could be achieved by slugging the mix with excess sulphuric acid. We also knew this was expensive on two counts, the cost of the acid and the maintenance of the equipment. We had heard steam might be an aid in granulating 1-4-4 ratios, so we started to investigate this angle. It didn't take us long to find out there wasn't a great deal known about this phase of granulation. However with encouragement from T.V.A. and a certain equipment manufacturer we installed Clayton Boilers rated at 100 horse power.

At our Danville Plant, where we had a separate meter for the gas used to generate steam, we found the fuel consumed cost us $0.05 per ton of fertilizer. All other costs, after the original installation, were nil. We found, as have others, that steam was only a temporary expediency and we soon started looking for better methods. The advent of phosphoric acid was an aid to better granulation, but caused other complications. The build up on spargers was much faster than previously. This condition was further aggravated by the use of steam and could shut you down in a short time. Still some added heat was necessary for good granulation.

At last year's meeting I stated we were trying hot water, but it was too early to make a statement. Hot water proved to be much better than the steam. However we use steam to heat the water through a heat exchanger. By doing this it cut our fuel bill from $0.05 per ton to $0.02 per ton. We are still working to eliminate the use of steam altogether, either directly or indirectly. One of our plant managers hit upon an idea that seems to have promise along these lines. (3) Like last year, I do not feel at liberty to make a statement at this time. More work needs to be done.

In conclusion, I would say that steam is an economical method for granulating 1-4-4 ratios if you do not have the means to eliminate it. However, I hope we will be able to eliminate steam and make a still better product. Although $0.05 per ton doesn't sound large, every penny we can save helps, particularly during these times. There still remains a great deal of work to be done in making a superior product at a more economical cost.

T. R. Schmalz

THE answer to this question cannot be a simple yes or no. Depending upon such factors as relative cost of P_2O_5 in super, triple and phosphoric acid, the cost of sulfuric acid, the grades manufactured in a given factory and the method of manufacture, steam may or may not be economically beneficial.

Steam is of no benefit in 1-1-1 ratio grades or other grades over 10% nitrogen. On the other hand, 1-4-4 ratio grades, low nitrogen grades and phosphate and potash grades can be granulated more economically with steam than with acids. In our particular case, where TVA ammoniators are used and where large tonnages of 1-4-4 grades are produced, steam generating and handling equipment was easily justified by saving of from 50 cents to $1.50 a ton.

Another benefit in addition to the economic considerations can be sighted. Where sulfuric acid is being used for granulation, a reduction in fume is accomplished by replacing acid with steam.

We have no first hand experience with phosphoric acid use, but from reports of others, the indication is that steam is beneficial when used with phosphoric acid.

QUESTION: *What is needed, equipment and operating wise, to successfully use steam,*

We do not yet know whether we are using steam to the utmost advantage. Depending on grade, rate, recycle rate, drying costs, and other such considerations, the optimum conditions of formulation and operation will vary.

As to equipment, our installations consist of package boilers, sized so that we have about 50 H.P. per 10 ton of plant capacity, which incidentally seems to be adequate without excessive overdesign. Steam is introduced in a pipe in the same manner as solution and acid, below the rolling bed. Avoidance of blow-thru is necessary and is accomplished by injecting the steam toward the ammoniator shell at from 40 to 60 PSIG.

QUESTION: *What process factors can cause failure in use of steam?*

Probably the biggest reason for not getting good results would be not getting enough steam into the bed to do what is being attempted. Even with adequate boiler capacity, if pipe line restrictions or something of that nature keeps steam from getting to the bed, the results, of course, are unfavorable. In addition, there must be enough soluble salts to form good pellets and enough free moisture to dissolve the soluble salts, just as where steam is not used. In this respect, it has been noted that in some grades, it is impossible to remove all acid and maintain well formed, hard pellets regardless of moisture and temperature in the ammoniator.

I realize that not much of a specific nature has been presented; however, in the spirit of the Round Table, any questions which I can answer, I shall be glad to at this time.

QUESTION: *Should I use a batch or a continuous production system?*

Specific details of the circumstances prompting this question might have considerable bearing on the answer. If starting from scratch to build a granulating plant, initial cost of equipment would probably be the same for batching as continuous.

The advantages of formulation flexibility, recycle handling, control and ease of operation which continuous systems have over the batching operation makes the continuous much more desirable, in my estimation. Tonnage rates required would also influence such a decision, 20- or 30-ton per hour plants would be more economical to run as continuous plants than as batch plants.

The thing to keep in mind, I should think, is that the ammoniation equipment is all that is in question, since the same equipment would be used from this point on in either case.

Question No. 4—A Panel Discussion on the Advantages and Disadvantages of Wet and Dry Scrubbers with Relation to Efficiencies, Particle Size Recovery Capabilities, Maintenance and Investment Costs

Countercurrent Versus Co-Current Drying of Granulated Mixed Fertilizers

N. K. Alfrey and G. L. Bridger

MOST mixed fertilizer granulation processes include a dryer as an essential part of the equipment. The least expensive and most popular type of dryer used is a direct-fired rotary tube equipped with lifting flights. Combustion gas enters either at the material feed end (co-current drying) or the material discharge end (counter-current drying). An objectionable fume is often vented to the atmosphere as part of the exhaust gases from either arrangement (5). The co-current dryer is more widely used than the countercurrent dryer (2) because the moisture evaporating from the feed material helps to prevent it from overheating when exposed to the hot inlet (throat) gases from the furnace. Overheating is undesirable because it can result in nitrogen loss from some of the materials as well as fume formation (1) (7).

Previous investigations have considered various aspects of fertilizer drying. Bridger and Burzlaff showed that composition of the material and temperature of the material were of major importance to rate of nitrogen loss during drying (1). Leister described many of the theories and principles of fertilizer drying (3). Nielsson emphasized the importance of the dryer to mechanical quality of the product (4).

This paper reports the results of laboratory and pilot plant scale tests conducted to determine the causes of visible dryer exhaust fume and to compare co-current and countercurrent drying.

Laboratory Studies

Laboratory equipment was used to determine the temperature of initial visible fume evolution from various granulated mixed fertilizers. For each test, fifty grams of fertilizer was placed in a 200 ml. beaker which was partially submerged in a sand bath. A thermocouple, located on the bottom of the material and connected to a potentiometer was used to determine material temperatures. Heat was applied slowly by a gas burner so that material temperatures above 275° F. increased at a rate of approximately 0.5° F. per minute. A glass rod suspended in the fume collected enough material on its surface for X-ray diffraction analyses.

Following are temperatures of initial visible fume evolution for six granulated mixed fertilizer grades:

Grade	Temperature, °F.
10-10-10	296
8-16-16	305
5-10-5	452
3-12-12	473
8-16-0	497
15-15-15	506

Shortly after initial evolution of fume, its intensity became very heavy.

Results of X-ray diffraction analyses of the fume showed that its major constituent for all grades except 8-16-0 was ammonium chloride and that ammonium fluosilicate and an unidentified phase were present in smaller concentration. The unidentified phase and ammonium fluosilicate were the major constituents of the fume from 8-16-0 grade.

The fact that fume evolution began in the 300-500° F. range, and that its intensity was great even with the small fertilizer samples, suggested that most of the fume from plant scale fertilizer dryers could be evolved from a relatively small proportion of the fertilizer that was overheated, even though the bulk of the material remained below this temperature range. Possible circumstances that would permit this are (1) very small particles of fertilizer suspended in the inlet combustion gas, which may be 1200° F. or higher, (2) fertilizer sticking to the dryer feed chute or flights, and (3) fertilizer spilling into the furnace. Consequently, pilot plant tests were carried out to determine the influence of these factors on fume evolution.

Pilot Plant Studies

Pilot plant studies were carried out with a small scale fertilizer processing unit, shown in Figure 1. It is patterned after the Davison Trenton process described by Reynolds, Alfrey and Rose (6). Preblended dry raw materials and recycle materials are fed continuously to the double paddle shaft pug mixer by a gravimetric feeder. The liquids are metered continuously to the pug mixer through variable area float type flow meters. The hot damp granulated material feeds by gravity from the pug mixer to the direct-fired 18″ x 54″ long rotary dryer tube which can be operated either co-current, as shown, or countercurrent by simply rearranging the feed and discharge chutes, reversing the tube, and relocating the upper operations platform, which is portable. From the dryer tube the hot drier material discharges by gravity into a conventional rotary cooler and from

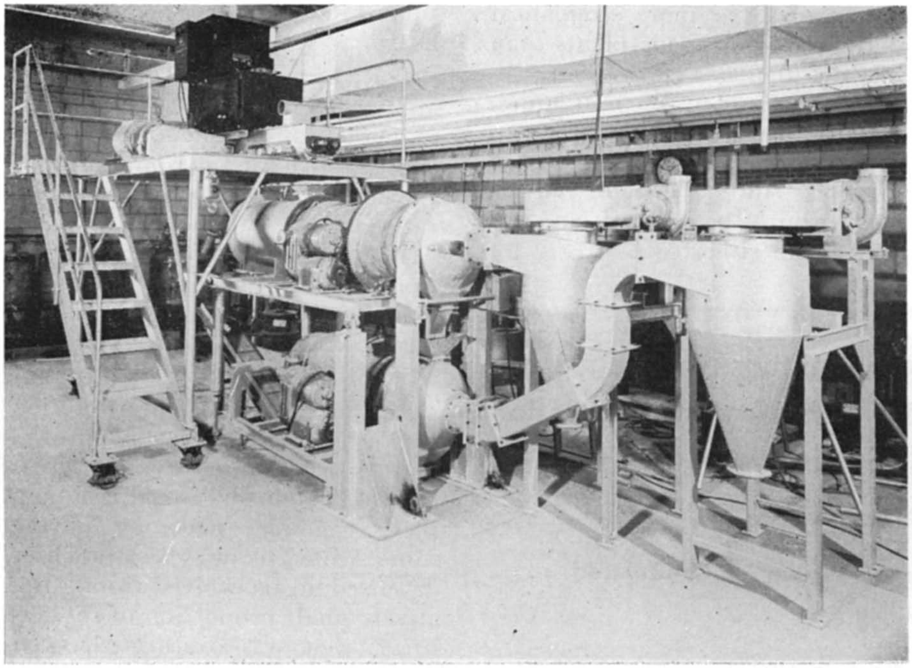


Figure 1. Experimental mixed fertilizer granulation unit.

there it is fed onto a product classifying screen. The production rate is from 50 to 200 pounds per hour of classified product.

Causes of Fume

With the co-current arrangement, a thick paste of wet 6-8-4 grade fertilizer was plastered on the surfaces of the feed chute, feed flights, and retention ring. Temperatures of the throat region and of material surfaces exposed to hot throat gases were measured with thermocouples connected to a recorder. Gas sampling apparatus arranged as shown in Figure 2 was used to determine and photograph variations in exhaust fume intensity which resulted from varying throat and material temperatures. Exhaust fume became barely visible when the material temperature reached 275° F. and the throat temperatures was 290° F. As these temperatures were increased, fume intensity also increased, and at 450° F. material temperature and 500° F. throat temperature a dense cloud of exhaust fume evolved.

Tests to demonstrate the influence of small particles in the dryer feed material on exhaust fume were made using both co-current and countercurrent drying. Previously manufactured 6-8-4 fertilizer, classified to 100% −6 +20 mesh U. S. standard sieves, was the control material. The test material was the same except that 20% of it had been ground through a

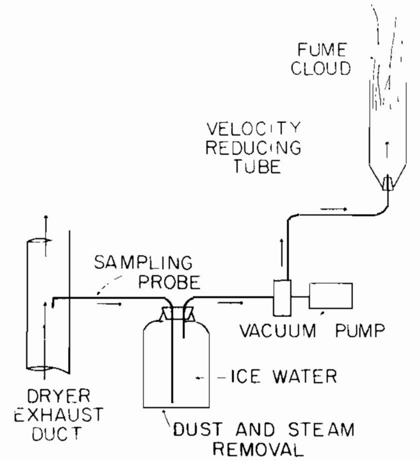


Figure 2. Apparatus for viewing fume intensity.

60 mesh U. S. standard sieve. For each test run the material, wetted to approximately 8% moisture was photographed using the apparatus shown in Figure 2. To correlate the data with actual production conditions, the procedure was repeated while granulating 6-8-4 from raw materials.

Dusts in 6-8-4 grade entering the co-current dryer caused barely visible exhaust fume at 350° F. throat temperature. The fume intensity was moderate at throat temperatures to 450° F. and higher throat temperatures caused more intense fume.

Using countercurrent drying, intensity of the fume was greatly reduced at corresponding throat temperatures, being barely visible at 700° F. and moderate at 1000° F. Eddy currents of air carrying dusts into the hot furnace were found to be a major cause of countercurrent dryer exhaust fume. Changes were made in the furnace design to eliminate the eddy currents. As a result the countercur-- with cold water, was fed continuously to the dryer at a 200 pound/-hour rate. The feed chute, flights and other parts exposed to co-current throat temperatures were cleaned before each operation to avoid formation of fume from decomposition of materials clinging there. The throat temperature was varied from 300° F. to 1200° F., while the temperature of the material leaving the dryer was controlled to 190° F. to 210° F.; this was accomplished by adjusting the material retention time. Influence of throat temperatures on the coarse and on the dusty materials for both co-current and countercurrent drying was observed and

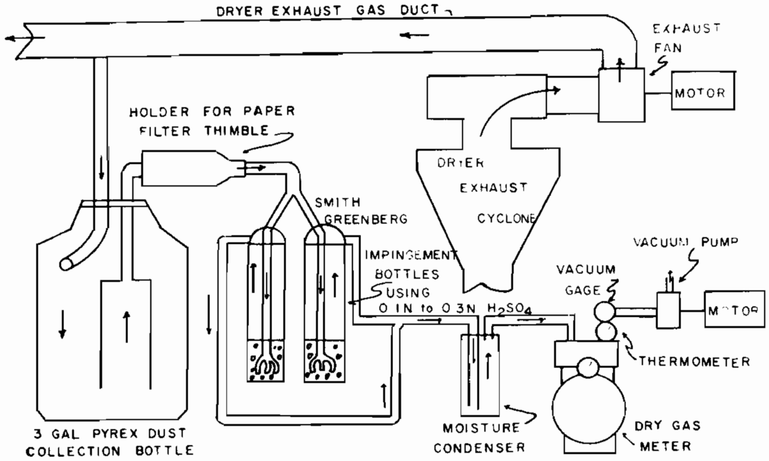


Figure 3. Dryer exhaust gas sampling apparatus.

rent exhust fume was almost completely eliminated even at elevated throat temperatures. After this change was made, 6-8-4 grade was granulated from raw materials and did not evolve visible exhaust fume at throat temperatures to 1200° F.

Co-Current vs. Countercurrent Drying

The pilot plant granulation unit was used for tests comparing co-current and countercurrent drying while producing 6-8-4 and 12-12-12 grades with formulas shown in Table I. Five co-current and six countercurrent runs were made to compare fume evolution, nitrogen losses, fuel usages and general operating performance. A gas sampling assembly shown in Figure 3, page 38 was used to determine fume evolution. The sampled dusts settled out in a 3-gallon pyrex jar which also permitted visual observation of fume intensity. Very fine dusts and fume were collected in 43 mm. x 123 mm. cellulose thimbles. Smith-Greenberg impingement apparatus using dilute sulfuric acid solution collected the ammonia. Nitrogen losses were determined from chemical analyses of material entering and leaving the dryer. A bellows type dry gas meter was used to measure propane gas fuel consumption. A start-up and lining-out operation preceded each test run to level out granulation, retention in the dryer, exhaust gas flow rate and temperature of the material leaving the dryer. By controlling these variables to predetermined levels, influence of type of drying on the remaining variables in the drying operation was determined. For each test run the length was precisely one hour, the dryer exhaust gas flow was approximately 60 cfm (N.T.P.) and the production rate was 100 pounds per hour. The recycle rate was 50 pounds per hour for 6-8-4 and 80 pounds per hour for 12-12-12 grade. Dryer feed and discharge samples were taken separately in triplicate at 10-minute intervals. Each exhaust gas sample was taken continuously during the one hour test run.

Table 1. Formulations

Ingredient		Lb./Ton	
	Analysis	6-8-4	12-12-12
Normal Superphosphate	20.4% A.P.A.	784	562
Triple Superphosphate	45.7% A.P.A.		274
Nitrogen Solution	37.0% N.	341	541
Sulfate of Ammonia	20.0% N.		249
Sulfuric Acid	60° Be'	62	129
Muriate of Potash	58.5% N.	138	407
Filler		782	
Total Lb./Ton		2107	2162
Evaporation "		107	162
Product "		2000	2000
Product Moisture		2.5%	1.0%
Ammoniation Rate Normal Super. (Lb. NH_3/Unit A.P.A.)		5.0	6.0
Ammoniation Rate Triple Super. (Lb. NH_3/Unit A.P.A.			3.3

BASIS: $\frac{H_2SO_4}{2.88}$ = Lb. NH_3 Reacted

Figure 4 shows the rapidly increasing concentration of fume in the exhaust gases as the temperature of the material leaving the dryer increases. Averages from six test runs using both types of drying with 6-8-4 grade showed that fume concentration at material temperatures of 275° F. to 290° F. was eight times greater than at normal temperatures of the material leaving the dryer (200° F.), and at 340° F. the concentration was twenty-five times greater than at 200° F. Fume with countercurrent drying was less than with co-current drying. With material leaving the dryer at 200° F. to 220° F., countercurrent fume for 6-8-4 and 12-12-12 grades was 50% of co-current fume concentration. The concentration at which the fume was initially barely visible was approximately 0.06 to 0.08 grains per cubic foot (N.T.P.).

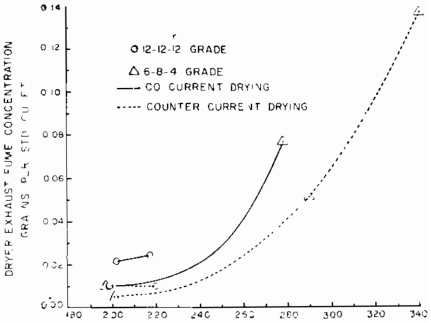


FIGURE 4 TEMPERATURE, °F, OF MATERIAL LEAVING DRYER

The nitrogen losses in the drying operation were calculated from the initial and final ratios of nitrogen to total phosphorus pentoxide as described by Bridger and Burzlaff (1). Figure 5 compares average nitrogen losses for both types of drying with 6-8-4 and 12-12-12 grades at various product temperatures (material leaving the dryer). The retention time for 6-8-4 grade with both types of drying was 25 minutes for the 200° F. product temperature tests, 12 minutes for the 275° F. to 290° F. tests and 8 minutes for the 340° F. tests. That with 12-12-12 was 11 minutes for the 200° F. tests and 12 minutes for the 220° F. tests for both types of drying. The data were not sufficient to permit precise interpretation of differences in nitrogen loss at the various temperatures and losses were considered to be substantially equal for the two types of drying with less than 2% nitrogen loss in all cases when the material leaving the dryer was 220° F. or less.

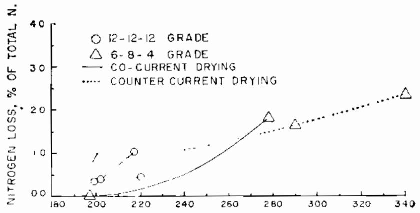


FIGURE 5. TEMPERATURE, °F, OF MATERIAL LEAVING DRYER

The following tabulation compares the fuel requirements **for** both types of drying:

	Thousands of B.T.U. per ton of dryer throughput	
	6-8-4	12-12-12
Co-current drying	800	570
Countercurrent drying	450	310

For each type of drying of 6-8-4 fuel consumption during two runs made at 200° F. product temperature and one run made at 275° F. to 290° F. was averaged as B.t.u. per ton of material throughout. Co-current drying required approximately 44 percent more fuel than countercurrent. Moisture losses for the two approaches were approximately equal. For 12-12-12, tests included both the 200° F. and the 220° F. product temperature. Co-current drying required 46 percent more fuel than countercurrent drying. The large radiation losses from the small scale equipment of course exaggerated the fuel savings of the countercurrent approach. It is believed that countercurrent drying would offer approximately 20 to 25 per cent savings in plant operations.

The difference in fuel requirements was reflected in throat temperatures and in exhaust gas temperatures. Figure 6 compares throat temperatures for the various tests. Countercurrent drying required 300° F. to 500° F. less throat temperature than co-current to achieve the same product temperatures. The exhaust gas temperatures were also significantly lower for countercurrent drying as shown in the following tabulated averages from four co-current and four countercurrent tests conducted while drying the material at 200° F. to 220° F. leaving the dryer:

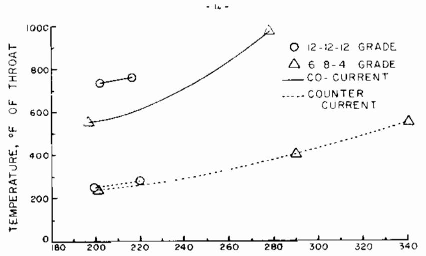


FIGURE 6· TEMPERATURE, °F OF MATERIAL LEAVING DRYER

	Material Temperature, °F. Entering Dryer	Material Temperature, °F. Leaving Dryer	Exhaust Gas Temperature, °F.	Retention Time Minutes
Co-current	156	206	217	16
Countercurrent	146	207	163	16

Operationally, countercurrent drying in the pilot plant presented three difficulties, all of which could be eliminated by simple design changes: (1) Eddy currents of air carried fertilizer dust into the furnace. The decomposition of this dust could cause serious fume evolution. (2) More precise fuel usage control was required than with co-current drying. A relatively small change in the fuel usage rate resulted in large temperature changes in the material leaving the countercurrent dryer. With care, the operators were able to manually control the material temperature to within 5° F. limits. However, properly regulated automatic control would probably be essential to good plant operation. (3) Dust collected in the countercurrent dryer exhaust hood in sufficient amounts to spill onto the operating floor in a continuous stream. This was believed to be caused by exhaust hood (breeching) design which permitted exhaust gas velocity changes to cause airborne dusts to drop out.

A diagrammatic representation of sources of fume formation in a co-current dryer and their elimination by use of countercurrent dryer are shown in Figure 7. With co-current drying, a small proportion of the fertilizer is subjected to decomposition temperatures by adhesion to the feed chute and flights, as fine particles in the inlet air stream, and by spillage into the furnace. With countercurrent drying the fertilizer which adheres to the feed chute and flights, and that caught as fine particles by the air stream, are in a low temperature zone. Furthermore in the hot zone of the countercurrent dryer, air temperatures are several hundred degrees lower than in the co-current dryer.

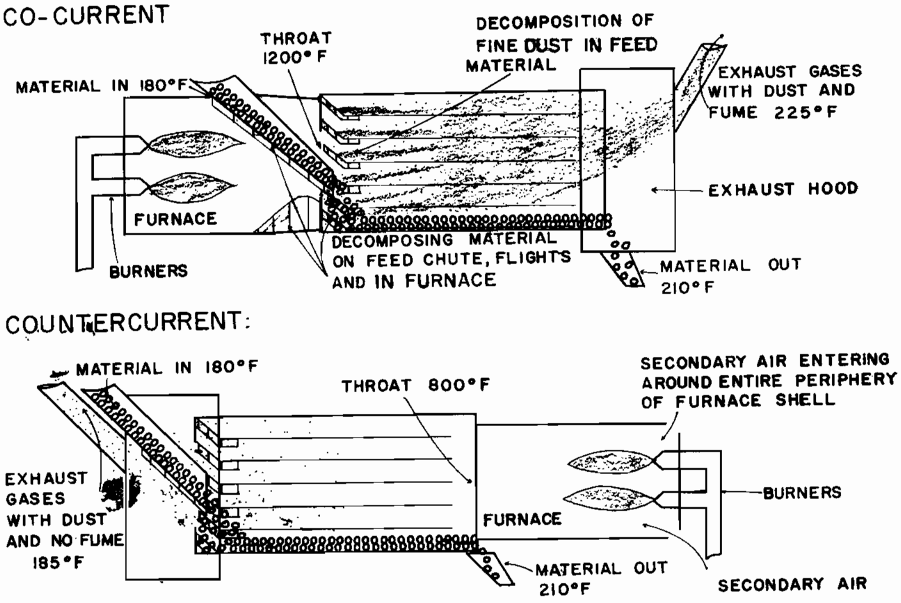


FIGURE 7. MAJOR SOURCES OF FUME AND THEIR ELIMINATION USING COUNTERCURRENT DRYING

Conclusions

Visible fume was evolved from granulated mixed fertilizers at temperatures above the 275° F. to 560° F. range; depending on their composition. Hot dryer throat gases caused fume by decomposing fertilizer materials. Sources of fume in a co-current dryer were small feed particles and materials adhering to the feed chute and feed flights. Countercurrent dryer fume was caused primarily by eddy currents carrying fertilizer dust into the furnace.

Co-current and countercurrent drying were compared while granulating 6-8-4 and 12-12-12 grades in a pilot plant. Countercurrent drying caused less fume, required less fuel and required more precise fuel usage control. Nitrogen losses from both were approximately equal and were less than 2% of the total nitrogen at product temperatures of 200° F. Co-current drying throat temperatures were 300° F. to 400° F. higher than those for countercurrent drying. Design of the countercurrent dryer was important for fume elimination.

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Operational and Performance Characteristics At Indiana Farm Bureau Cooperative Fertilizer Plants

L. M. Leach

1. Description of Hydro-Filter:

A cone-bottomed steel housing containing two packed beds above the contaminated gas inlet. The lower bed (filter bed) has a 3″ to 4″ layer of glass marbles, and the upper bed (demist bed) has a 6″ layer of Berl saddles. Large orifice, low pressure spray nozzles impinge water onto the bottom of the filter bed and the top of the demist bed—these sprays operate respectively at 20-25 lbs. and 5-7 lbs.

Pressure drop through the unit is 5″ to 6″ water gauge.

2. Operation:

The dust carrying gas stream expands into the lower part of the housing, then flows upward through the marbles at high velocity (4000 to 6000 feet per minute). Water from the sprays is carried thru the marbles to form a violent turbulent layer (4″ to 8″ deep) above the top marble layer. Collection of dust is by:

Condensation effect on entry of gas into scrubber—this causes some agglomeration of small particles.

High velocity impingement of dusts onto marble surfaces.

Impingement on bubble surfaces and containment within bubbles.

Impingement on water droplets.

The turbulent water layer is continuously replenished by water drawn up thru the bed; therefore, since the air column can support only so much water head, the excess water (which contains dusts and absorbed gases) continuously flows back thru the bed. This backflow is at a continuous rate but for any specific area of the bed it is an intermittent backflow. The back flow washes dusts and slimes off the marbles to prevent blinding of the bed.

The dirty water contains both solubles and insolubles and drains from the cone bottom to a tank from which it is recirculated back to the filter bed sprays at a rate of 3 gpm per 100 CFM scrubber capacity.

Water droplets picked up by the gas stream in the turbulent layer are removed by the saddle bed—rapidly changing air direction throws out the water drops and these drop down to the turbulent layer.

A timer and solenoid valve are furnished to wash this bed with fresh water for 30 seconds each 15 minutes. These upper sprays operating at 5 to 7 lbs. Pressure creates large water drops to prevent reentrainment. This wash water is fresh water make-up to the recirculating system to replenish evaporation loss—it amounts to approximately 1/7 gpm per 1000 CFM capacity of scrubber. These scrubbers can handle dust loads up to 40 grains per cu. ft. Water recirculation, of course, is increased to keep lower bed cleaned.

3. Performance:

When this unit was under consideration for scrubbing dryer gases there was no specific data available regarding its performance in the fertilizer industry. The troublesome ammonium chloride is considered to have fume characteristics – formed by condensation and usually less than 1 micron in size. The Hydro-Filter was known to have 100% collection efficiency on dusts 2 microns or larger, and tests on the following types of fume and dusts showed:

Item	Efficiency
Lime Kiln	99+% insolubles: Ca, etc. 92% solubles; Na, etc.
Electric steel furnace	77% fume known to range .05 to .5 micron

A 2000 CFM test unit was tapped into the stack beyond the cyclones to measure solids being discharged from the stack and determine Hydro-Filter efficiency. Tests were made on 5-20-20 and conducted by manufacturer's personnel with quantitative weights of filters made by the plant's contract chemist. Filters used were an absolute glass type which are guaranteed to catch particles 0.2 micron or larger (cigarette smoke).

Inlet gas temperatures were 200-220° F. and outlet temperatures from the Hydro-Filter were 100-120° F. when using fresh water for scrubbing.

Ammonium chloride appeared on the outlet filters but none was on the inlet filters; this indicated the chloride entered the scrubber in gaseous phase but was sublimed or condensed before hitting the outlet filter. No quantitative measurements were made to determine efficiency of chloride collection, because this type of fume in gaseous phase is beyond the range of low pressure loss scrubbers.

The series of tests on 5-20-20 showed an overall efficiency of 95% for removal of dusts leaving the cyclones and was considered conservative due to absence of any chloride measurement on the inlet side.

A 30,000 CFM unit was purchased for the Indianapolis dryer which operates at 30-40 tons per hour. Tests on 5-20-20 production showed:

Inlet Loading Grains per Std. cu. ft.	Outlet Loading Grains per Std. cu. ft.	Efficiency
1.542	.0556	96.4
1.000	.0514	94.9
.874	.0254	97.1
1.015	.0255	97.5

If the normal cyclone emission is 1 grain per std. cu. ft. then approximately 260 lbs. dust are being thrown out the stack each hour.

$$\frac{30{,}000\text{ cu. ft.}}{\text{Minute}} \times \frac{60\text{ min.}}{\text{Hr.}} \times \frac{1\text{ gr. dust}}{1\text{ cu. ft. air}} \times \frac{1\text{ lb.}}{7000\text{ gr.}} = 257\text{ lbs./hour.}$$

Applying the 95% removal efficiency of the scrubber, dryer emissions would be reduced to approximately 13 lbs. per hour. This type of emission is composed of such small particles that no fallout will occur near the plant—rather they will be dispersed by wind action over such an area as to be unnoticed.

At that plant the stack has a vapor plume which disappears rapidly.

It seems the difference in the plumes of the two plants is due to inlet gas temperatures—at Indianapolis the temperature is high 180-220° F., while at Jeffersonville it is only 130-150° F. due to blending of gases from mixer, dryer and cooler. The lower inlet temperature may induce a formation of solid chloride since the gas is below the sublimation or gaseous phase temperature; if this is true, removal efficiency would be higher as evidenced by stack appearance.

4. General:

At both plants the recirculated water to the scrubbers picks up soluble and insoluble compounds. This solution is bled off the pump line and goes to the ammoniator for control of granulation. Therefore the collected dusts are retained in the system and not thrown away. At our Jeffersonville Plant on approximately 26,000, we have only cleaned our sludge tank 4 times and one was during summer to check condition of tank. It is not too different at Indianapolis, however, we have the extra water comming to the sludge tank from the Peabody Ammoniator Scrubber, the Roto Clone on cooler and the Air Compressor after cooler water.

Recirculating pump at Jeffersonville is ordinary cast iron and has given good service for approximately 26,000 tons fertilizer production in spite of the solids and corrosive type solutions handled.

Characteristics of various types of dust control equipment:

Type	Advantages	Disadvantages
Cyclones	Low cost, low pressure drop (2″), can return dust to system, low maintenance	Cannot collect below 10-15 microns.
Wet Scrubbers Low Pressure Drop-4″-6″	Can be used in series with cyclones, moderate cost, solids can be returned to system. Collection to 2 to 5 micron range.	Vapor plume. Condensation of moisture in stack during cold weather. Some fume gets thru if inlet temperatures high.
Wet Scrubbers 15″-30″ Drop	High efficiency on fumes same advantages as for low pressure wet scrubbers	High cost of operation—power. High water consumption and high pressure nozzles. Vapor plume. Condensation in stack.
Dry Bag	High efficiency Moderate pressure loss, same advantages as low pressure scrubbers.	High initial cost Difficulty in disposal of fine, dry dusts. Temperature control desirable to protect bags. Possibility of mudding in bags with wet gases. Corrosion.
Electro-Static	High efficiency Low pressure drop—2″	High cost Disposal of fine, dry dusts Corrosion.

5. Installation Cost:

The installation expense varies considerably depending on local conditions. It is interesting to note complete installations (except Hydro-Filter) was approximately $10,000 at one plant and $18,000 at anothers.

Baghouse Operation On Fertilizer Dryers

E. L. Felch

ONE of the major problems in the operation of a continuous ammoniation unit has been the persistant fog or haze that is emitted from the dryer. Many complaints have been received, even from plants operating in rural areas where neighbors are fairly remote and dispersed. Three possible solutions to the problem exist at present. One method is a stack of sufficient height that will carry the haze above the point that atmospheric inversions will not bring the haze to ground level. Another solution is a venturi scrubber with 30 to 50 inches of water pressure drop across the throat with water induced into the venturi as the absorbing medium. The third successful method is the bag house.

Each method has its drawbacks. The stack should approach 300 ft. in height for best success. The wet gases in the dryer effluent are among the most corrosive materials we have handled and the stack must be lined with alloy steels or organic materials, greatly adding to the capital outlay. The venturi scrubber requires 300 to 500 HP of power. Maintenance problems of the venturi and high speed fan are aggravated by the corrosive atmosphere. The bag house solves most of the aforementioned problems but operation is very critical and dictates the maximum level of production that any given unit can run.

Successful operation of a bag house depends to a great extent on the understanding of the basic problems and limitations of each piece of equipment used in the complete unit and each piece must be designed to work with every other piece. Thus the oil or gas burner must have sufficient control range to maintain a fixed output temperature at the end of the dryer from no load to the maximum drying rate required. The dryer must have a certain diameter to length ratio to give proper retention time. The bag house size is dependent on the dryer diameter as air velocities through the dryer are very critical in the proper classification of dust particles that must be fed into the bag house. The induced draft fan must be able to have sufficient reserve power and capacity that the damper controls can readily hold the air velocities through the system constant despite pressure fluctuations in the baghouse.

Flues must be sized and designed so that no fallout of materials occurs. Insulation must be thorough and complete to avoid any internal water condensation that might carry into the baghouse.

Two of the basic problems in the operation of the baghouse are gradual buildup of fertilizer inside the tubes until the weight of material will tear the bags from their supports and the formation of fine dusts that completely seal the cloth surfaces to the point no air can pass. Buildup can be prevented by keeping the dewpoint of the inlet air below 150°F. and the dry bulb temperature above 260°F.

High pressure drops across the bags due to lack of porosity in the unit can be controlled by maintaining sufficient air velocity in the dryer. This in turn will insure that enough coarse particles will be carried into the baghouse that proper cake permeability will be maintained regardless of dust loadings and cake thickness.

In a straight tube dryer this velocity must be maintained at not less than 600 ft. per minute. However, velocities above 800 ft. per minute will cause too rapid material carry-through the dryer and insufficient drying will result.

On new designs, the above limitations will control the selection of the baghouse and dryer size. The total water required to granulate the most difficult grade should be selected. This will be usually a 1-4-4 formula. To this should be added the normal moisture in the raw materials, in the recycle, humidity of drying air, and fuel to water conversion in burning. From this, the volume of drying air can be calculated to give a final dewpoint of not more than 150°F. Dryer diameter can then be calculated to keep the volocity between 600 and 800 ft. per minute. Dryer length is usually 7 to 8 times the diameter.

Bag house size is roughly based on having ½ sq. ft. of cloth area per cu. ft. per minute.

On existing dryers the installation of a baghouse will fix the maximum tonnage output to precalculated levels for any given formula.

Fan size and output should be designed to handle the above volumes with 13″ to 14″ of static pressure rise across the fan. This will allow the system throttling damper sufficient leeway to overcome momentary buildup and keep the system volume constant. Normal pressure drop across the bags ranges from 2″ to 4″ and in average operation the total pressure drop across the whole system will seldom exceed 10″ at the fan inlet.

Many things will happen in the operation of the baghouse ranging from minor plugging problems to melting down of the fabric bags. Part of these troubles will be due to improper methods of operation, lack of periodic inspection and maintenance, and oversight on the designers part to provide safety controls to protect the equipment in case of failure.

The unit must be preheated to above 200°F. before any feed is introduced in the dryer. This takes from 15 to 20 minutes and it is well to install a thermometer on the discharge side of the baghouse that is readily accessible to the operator. At this time the system is empty and the bags clean and the amout of heat absorbing material in the unit is at a minimum. This is the most dangerous condition in that small increase in fuel use will result in very rapid increases in temperature and melt down of the bags can occur in a very short time. Temperature controls must act rapidly and the temperature sensing devices must be able to respond quickly or overheating can occur. It has been advantageous to install exposed thermocouples or pressure bulbs directly in the gas stream and not use well or protective covers over the sensing devices. These must be cleaned periodically. A completely independent high temperature shut down apparatus should be installed rather than depend on the temperature control unit to keep temperatures within safe limits. This should also be equipped with fail-safe mechanism in case of thermocouple troubles or temperature bulbs leaking.

At times air filtration, induced draft fan failure, burner troubles or slugs of liquid directly into the dryer will cause moisture precipitation into the bags. The resultant cake will have to be washed off and this can be accomplished by washing the bags in several changes of clean water. Do not use soap or detergents.

Plugging of the lower hoppers and screw conveyors happens frequently and is usually due to air leakage into the bottom of the hopper which prevents the material from flowing out. Daily inspection and cleaning of the air valves are required. Damper problems are ever present and must be taken care of at once if more serious troubles are to be avoided. Dampers must clost tight and open easily to let the bags discharge during the shakedown cycles. If excessive pressure differences develop between compartments, some flow of air will interchange between the hoppers and serious plugging problems occur.

Some grades build up on the impingement baffles and flake off in large pieces that will plug the lower openings. Rubber impingement plates have been tried but they do not take the punishment at the elevated temperatures.

Daily inspection of the unit will reveal possible troubles. Signs of metal corrosion on the inner walls means that too high dew points or too low temperatures have occurred. These can come from forced dryer shutdowns, air infiltration, duct plugging and a myriad of other causes but if not run down and corrected they will cause rapid deterioration of the bag house.

It is impossible to go into all the troubles in detail in such a brief time. Every unit has its own idiosyncrasies and in many cases some modification of operating procedures must be made to obtain satisfactory performance.

In closing, The American Agricultural Chemical Company would like to express its thanks to the other fertilizer manufacturers who were kind enough to allow our engineers to inspect and run tests on similar equipment. We thank you.

Question No. 5—What Control Data Should be Collected by Plant Operators for the Efficient Operation of a Granulation Process?

Rodger C. Smith

As we know there are being made tremendous advances by the process industries in the use of control data and the application of instrumentation. The two primary advantages gained are reduced labor costs or increased labor productivity and improved product quality, both extremely important. Ways have been found in the fertilizer industry to effectively use certain control data but only limited progress has been made in the utilization of instrumentation. Although there are certain problems including small plant size and physical state of the fertilizer, it is reasonable to expect further application of instrumentation to fertilizer granulation.

In accomplishing control of a graulation process, certain data can be obtained continuously or is available in advance. For the important question of analysis obtained, however, we have the severe disadvantage of elapsed time since we depend largely upon the control laboratory. Study of the practical applications of reliable instruments can have the objective of better product quality and less dependence on the control laboratory with its inherent time lag, as well as the objective of lowering costs.

Now what data should be obtained in the efficient operation of a granulation process. This can vary widely. Let me enumerate what appears to be a middle course approach to the collection and use of data at present.

First, we have the incoming materials on which accurate information on nutrient analysis, moisture and screen analysis is basic. Moisture analysis is wanted for formulation and control of degree of wetness in the mixer. The screen analysis of granules formed, therefore important to know, in addition to appraising the ammoniation capacity of superphosphate.

Feeders and meters require calibration and scales need to be checked. A record of those calibrations leads to better understanding of the instruments characteristics and may predict needed repair. If using viscous material such as wet process phosphoric acid or spent sulfuric acid, data is needed on the relation of temperature to flow rate otherwise calibrations have to be made. To the extent that information relating to setting of this equipment can be catalogued for quick reference, time is saved and errors avoided.

Certain daily records are required for inventory purposes which also aid control. Other information can be collected daily which can be useful in the following day's operations or later. These include the number of batches, the total amount of each liquid metered during a day or shift and the dry ingredient feeder revolutions or elapsed time of operation during the day or shift. It is well to know approximately what rate of water addition is used to guide later formulation. The moisture balance is now a familiar article in granulation plants. These analyses obtained once or more times daily dictate fuel input to the dryer immediately and can guide formulation, air volumes required for dryer and cooler and the need for use of coating agents. An overall evaluation of the daily operation by the foreman or superintendent is very useful in spotting troublesome process or equipment operation and in enabling week to week appraisal of operation.

Temperatures are very important. Unless personnel have considerable experience with granulation, the installation of equipment to record continuously temperatures at key locations can lead to more rapid understanding of the process and better efficiency. Typical locations for thermocouples used with a six point potentiometer are the fertilizer as discharged from the ammoniator, the dryer and the cooler and the air ambient, ex-dryer and ex-cooler. The ex-dryer air temperature is of particular value to controlling agglomeration and water removal. Some installations automatically control the dryer burner from the ex-dryer air temperature. Now that nitrogen solutions with lower ammonia content and higher salting out temperature are being used, a dial thermometer installed in the nitrogen solution line near the meter is useful. Likewise, one in the acid line is important if calculating viscosity.

The routine product sampling normally includes a composite obtained following classification enroute to storage bin. As yet the analyses of these composite mixing samples are of utmost importance to formulation, check or human and mechanical competence and evaluation of process equipment. Information useful on these reports include date of sampling, laboratory sample number, the bin in which the mixture is stored and the tons mixed. Analytical data on the report normally includes total nitrogen, total phosphoric acid, available phosphoric acid, potash and, on occasion, screen analysis.

This is data which can be used effectively in controlling a granulation process. Additional data should be obtained if the means of obtaining the data and its utilization justify it.

Question No. 6—A Discussion of the Economics of Instrumentation as Related to Checking the Air Flow System Through the Dryer, Furnace, Cooler, and Other Duct Work Systems.

D. E. Bonn

Fertilizer Plant Dust Control Low and Medium Pressure Drop Wet Collector

THERE are many different fertilizer processes – dry mix plants, ammonium nitrate plants, urea plants, and super phosphate plants. Many of these processes require some type of dryer and cooler.

Following are the major dust producing points.

Ammoniator or Wet Mixer

The ammoniator is a steel cylinder approximately 5′ in diameter and 9′ to 11′ long. It is used to introduce ammonia into super phosphate, or into a mixture of superphosphate and other fertilizer ingredients, to make complete fertilizer mixtures. The resulting fertilizer compound is wet and must be dried. There is little dust but there is a considerable amount of NH_4Cl fume. Ammonium chloride fumes are less than one micron in size. As these fumes, along with some ammonia gas must be exhausted, a collector is normally required. Present size ammoniators require about 6,000 to 8,000 cfm for control.

Dryer

As the fertilizer is discharged from the ammoniator it is fed to a dryer approximately 8′ to 10′ in diameter and 35′ to 40′ in length. Dryers are normally oil and gas fired and require anywhere from 20,000 to 50,000 cfm. Dust and exhaust gases from the dryer are passed through dry cyclones (the collected material is normally returned to the process). In many instances an additional collector will be required for air pollution.

Cooler

The fertilizer must be cooled before bagging or storing. Coolers are usually cylinders 10′ in diameter, 35′ to 40′ long. The cooling air volume is from 20,000 to 40,000 cfm. Exhaust air from the cooler goes through a cyclone and to atmosphere or a collector. There is considerably less material carried over from the cooler than from the dryer.

Screen

As the fertilizer comes from the cooler, belt conveyors take it to an elevator where it is discharged onto a screen. As loading is heavy and material somewhat valuable, dry collection is desirable; however, the screen exhaust is sometimes vented to the dryer primary collector. Use 50 cfm per square foot of screen with good hooding.

Mixing Pans

Mixing pans are used to mix the dry phosphate rock with sulphuric acid. The acid and phosphate rock dust are dumped into mixers in batch form and remain there for the completed chemical reaction. It is then dumped through an opening in the center and falls to a "Den" which holds approximately an eight hour production from the mixing pan. After the superphosphate has "set" a few hours, it is removed from the den and taken to the storage areas. The acid mists (hydrofluoric) given off in the mixing pans and the dens, must be removed as they are formed, to prevent smothering of the chemical reaction.

Most plants have some type of dust control at this point because it must be vented.

Material Handling System

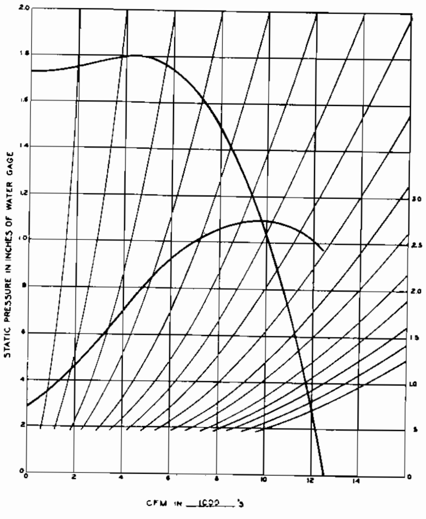
There are many other dust producing operations such as belt conveyors, elevators and bagging stations. These points can be controlled by separate collectors or exhausted through dryer or cooler cyclone. Generally after the material has passed through dryer and cooler it is best to collect it dry, since the material has a salvage value. Process dust discharged to the atmosphere from stacks not equipped with effective air cleaning devices permits the coarser particles to settle in the general area of the stack. Such settlement can be a nuisance to neighborhood property and many times actually causes damage from chemical attack. Finer particles stay in suspension for prolonged periods of time contributing to the air pollution problems of the community. Sub micron particles, such as ammonium chloride are typical of stack effluents that tend to stay in suspension for long periods, causing the smogs that reduce visibility and shut out sunlight where meteorological conditions prevent their dispersion to the conisphere.

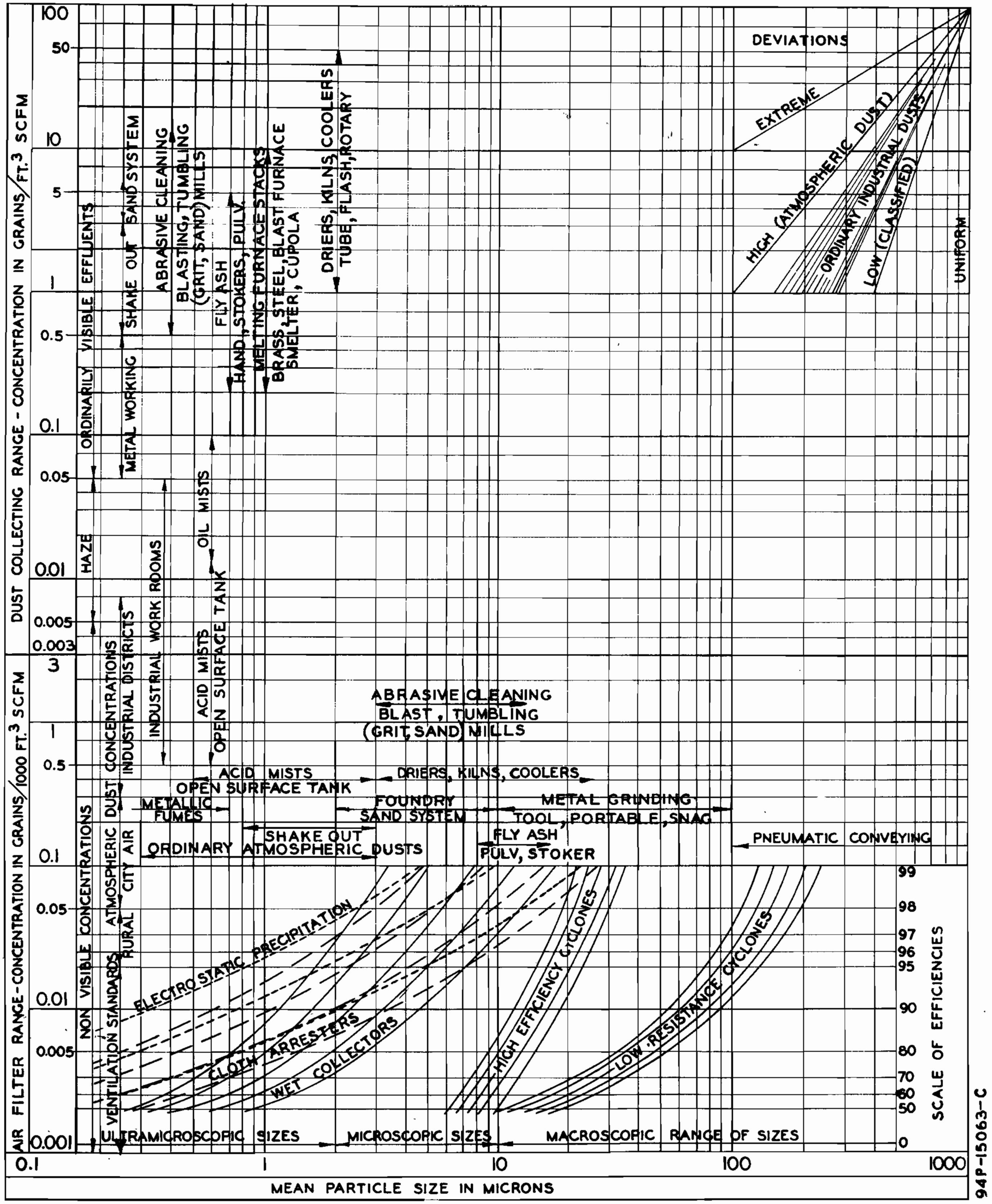
In the Fertilizer Industry the biggest offenders from the standpoint of quantity of material and fumes, are the dryer and cooler. On a typical installation 25 ton/hr. plant, measurements made on inlet to dryer cyclone show approximately 13,500 lb./hr., cooler cyclone approximately 363 lb./hr., being exhausted from dryer cyclone and 18 lb./hr. from cooler cyclone.

The Type W or N ROTO-CLONE have been widely used for exhausting dryer and cooler stacks. to date there have been more than 35 installations made exhausting over ½ million cfm.

The Type W ROTO-CLONE is a combination fan and wet dust collector. It is basically no larger than a centrifugal exhauster and is shipped as a completely assembled unit. High collection efficiency is

To determine performance at another RPM multiply:
1—CFM x K
2—SP x K^2
3—BHP x K^3
Where K is new RPM divided by RPM shown at right.





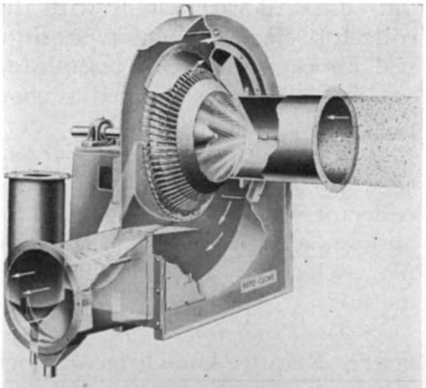
RANGE OF PARTICLE SIZES, CONCENTRATION, & COLLECTOR PERFORMANCE

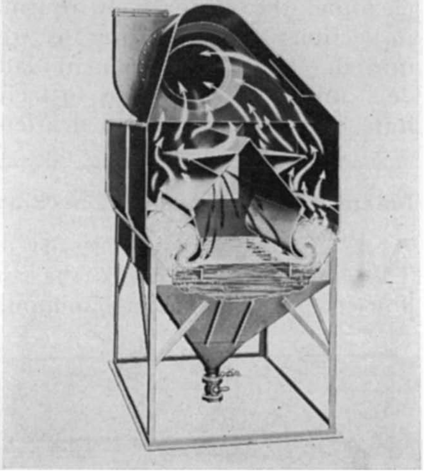
COMPILED BY S. SYLVAN APRIL 1952 : COPYRIGHT 1952 AMERICAN AIR FILTER CO. INC.

ACKNOWLEDGEMENTS OF PARTIAL SOURCES OF DATA REPORTED:
FRANK W.G. - AMERICAN AIR FILTER - SIZE AND CHARACTERISTICS OF AIR BORNE SOLIDS - 1931
FIRST AND DRINKER - ARCHIVES OF INDUSTRIAL HYGIENE AND OCCUPATIONAL MEDICINE - APRIL 1952

maintained by moving a fine film of water over a large number of specially designed blades, the dust and water being dynamically precipitated to the blade tips, where the dust, a small amount of air, and water are carried to an expansion chamber. The expansion chamber separates the air from the water. The slurry (dust and water) is then returned to process or overflowed to the sewer. The Type W ROTO-CLONE maintains constant efficiency over the entire operating range regardless of speed or air volume changes. This is important where dryers are operated beyond their normal rated capacity.

The Type N ROTO-CLONE is an orifice type collector where collection efficiency depends upon washing the gas stream with a large quantity of water and several air directional changes. The N ROTO-CLONE will also maintain constant efficiency over its entire operating range. The W and N ROTO-CLONE, have the same efficiency, the difference being in amount of maintenance required.





Efficiency Chart

Grade	Primary Inlet	Collector Outlet	Collection Eff.	Final Inlet	ROTO-CLONE Collector Outlet	ROTO-CLONE Collection Eff.	Overall Eff.
15-15-15	225 lb. min.	0.440 lb. min.	99.7	0.440 lb. min.	.0133 lb. min.	97	99.9

Depending upon the grade produced, which determines the amount of fume generated, the ROTO-CLONE efficiency will range from 90% to 97% efficient by weight. The average particle size of the fumes range from .1 micron to approximately 1 micron. Generally the higher the nitrogen content the less fumes generated.

Sylvan Chart

It must be remembered that visibility of an effluent will be a function of the light reflecting surface area of the escaping material. Surface area per pounds increase roughly as the square of particle size, which means that the removal of 80% to 90% of a dust load can remove the coarse particles without altering the stack discharge appearance.

It is also difficult to compare the efficiency claims of manufacturers in a given group of collectors. The absence of a standard method of small micron particle measurement can result in a variation in performance reported dependent on measurement equipment used.

The primary advantages and disadvantages of a wet collector system are as follows:

Advantages	Disadvantages
Small space	Corrosion protection required
Flexibility	Depending upon type of plant, water disposal
Maintained efficiency over entire operating range	On certain grades, a visible ammonium chloride plume
Low initial cost	
Low operating cost	
No auxiliary heat required	
Can be operated without regard for preheating.	

In purchasing a dust collector, there are a number of factors to be considered. I have on slides a number of check points which may be of help.

Maintenance. Basically a wet type collector constructed of proper corrosion resistance material is the easiest to maintain, excluding the dry type primary collector.

Dust Collector Application Check List

1. Dust Characteristics:

(a) *Mean Particle Size and Range.* The coarser the particles and the narrower the size range, the easier collected.

(b) *Concentration, Grains/Scfm.* The heavier the load, the higher the collector efficiency required. Calculate and evaluate pounds per hour escaping collector.

(c) *Abrasive Characteristics.* Abrasion is a function of material and its particle size, shape and concentration. Removal of high percentage of coarse particles may not materially reduce wear on exhauster or final collector.

(d) *Adhesive, Sticky, Packing Characteristics.* Materials with such characteristics can plug some types of collectors.

(e) *Bridging Characteristics.* Particle size or nature of material can be involved. Clogging of discharge ports or collector passages can occur.

(f) *Fire or Explosion Hazard.* Evaluate especially where collected material is organic such as grain, spices, etc.; plastics, coal, aluminum, magnesium. The smaller the particle size, the greater propagation rate. Hazard greatest where mechanical attrition in process occurs, or where dust loadings are very high as in pneumatic conveying systems.

(g) *Hydroscopic Materials.* Problems same as item "d," especially where air approaches saturation.

(h) *Foreign Materials.* The biggest headache for many types of collectors. Certain industries appear unable to keep workman from disposing of cleaning rags, cigarette packs, and lunch wrappers through exhaust hoods provided for their comfort or protection.

2. Gas Steam Characteristics.

(a) *Volume, CFM.* If large, when possible weigh relative merits of breaking up into smaller systems. Smaller systems provide greater flexibility, increased equipment cost, and maintenance points.

(b) Temperature. Where temperature exceeds 170°F, collector selection may be influenced.

(c) *Mist, Steam Water Vapor, Other Condensation Vapor.* Can cause mud formation detrimental to some collector designs. May require added heat or insulation to prevent condensation.

(d) *Corrosive Gases.* Corrosion protection can require expensive special material of construction, especially where wet type collectors are employed. Check carefully for corrosion any time combustion gases are involved.

3. Collector Selection.

(a) *Efficiency Required.* State as overall collection by weight percentages of entering load as collected by fractional size groups of particle size; by number of particles per cubic foot (where air is recirculated to workroom); by visible appearance of cleaned gas (usually expressed vaguely in degrees of opacity).

Efficiency required will depend on plant location, dust concentration, local meteorological problems; community or state regulation. The larger the exhaust volume, the higher the efficiency usually required with increased "mass rate of emissions."

Good rule is to select equipment with highest order of cleaning efficiency available at reasonable cost and reasonable maintenance.

(b) *Available Types.* Eliminate those types not suited to the problem due to factors discussed above.

(c) *Indoor or Outdoor Collector Location.* Space required often the determining factor. Outdoor installations suffer most from neglect; may require added protection against freezing or condensation.

(d) *Installation Work Required.* Will vary widely with the collector selected. Some types shipped knocked down for assembling on job site; others shipped as completely assembled units.

(e) *Provision for Material Salvage or Disposal.* Can influence collector location, arrangement of and capacity of dust storage hopper, selection of dust handling methods.

(f) *Provisions for Maintenance.* Require knowledge of work involved. The higher the order of cleaning, the more likely routine inspection and servicing is required. Include permanent ladders and access platforms to facilitate and encourage needed attention.

Study operation and maintenance instructions for design under consideration.

(g) *Need for Make Up Air Supply.* If total volume exhausted from building by all systems exceeds two air changes per hour, give serious consideration to make up air supply.

(h) *Installation, Operation, Maintenance Costs.* Collector purchase price is often small portion of total cost. Installation cost will vary with collector and should be evaluated after erection, foundation, wiring, plumbing, disposal equipment and accessory equipment prices are estimated.

Means and Methods for Checking Air Flow From Dryers, Cyclones, Etc.

MANY times it is necessary to measure or check the air flow from dryers, coolers, ammoniators, ventilation systems, etc. Normally, when you purchase machinery, requiring air for cooling, ex-

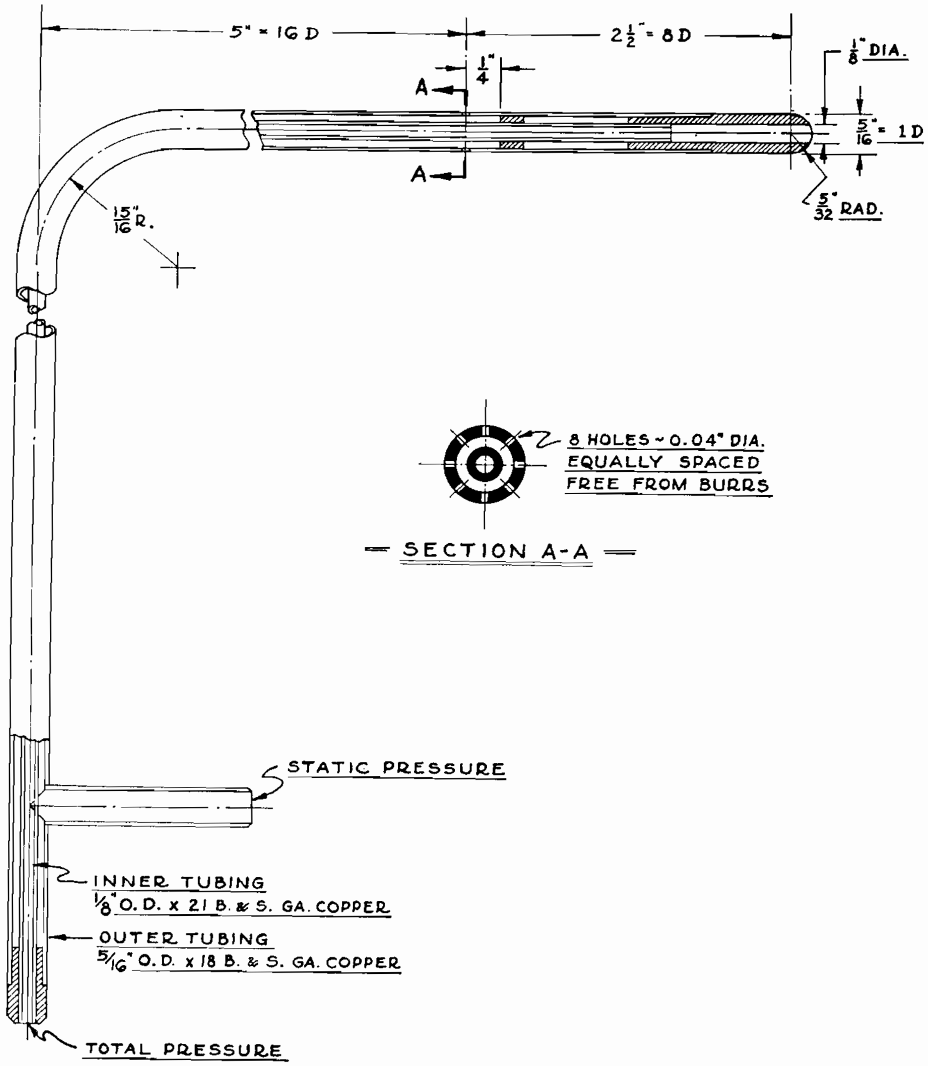


PLATE IX

STANDARD PITOT TUBE

hausting, or drying, the manufacturer either includes a fan of sufficient capacity or advises exactly how much air volume and horsepower is required, and the fan is purchased separately. How many times after the plant is in production is the fan system checked to see that it is delivering the designed air volume? Many times after several years of operation duct work is changed, increasing or decreasing the air volume. Not moving the proper air volume can mean improper drying, increased material carryover, higher operating costs to you. The real heart of any dryer or cooler is the air prime mover.

There are several instruments available for measuring air volume.

1. Anemometer. Normally used to measure air flow into hoods or through grills. Generally not suitable for use in measuring flow in duct work. Meter reads velocity.
2. Velometer. Generally used to measure velocity in lower range—100 fpm-700 fpm. Not generally suited for dusty air conditions.
3. Pitot Tube. Most widely used air measuring device. It has no moving parts and can be used in extremely dusty atmospheres. The pitot tube needs no adjustment and is very reliable. With a little practice, quite accurate readings can be made in a very short time.

For this discussion we will only consider the pitot tube. To measure the velocity in a duct, a pitot tube, inclined manometer, or U-gauge and thermometer are required. To obtain accurate readings, a velocity traverse in the duct must be made. Normally, in ducts larger than 30-inch diameter, a 16-point traverse is made. For quick checks, 4 to 6 points are usually enough. The duct to be measured is divided into a number of equal areas and the velocity measured at the center points of each. The *individual velocities* are average, not the individual *velocity pressures.*

With both the static tap and total pressure tap connected to the U-gauge, the pitot tube is inserted into the duct with the tip end pointed against the flow of air and parallel to the pipe. The point being measured should be, if at all possible, at least 10 pipe diameters from any pipe change, elbows, or any obstruction. Where this isn't possible, use the longest length of straight pipe run available.

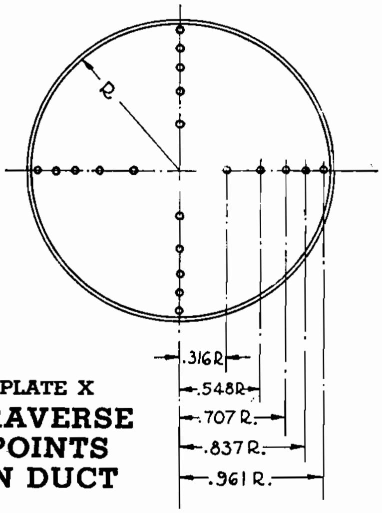


PLATE X
TRAVERSE POINTS IN DUCT

The pitot tube measures static, total, and velocity pressure. By definition:

Static pressure is a measure of the pressure exerted in all directions by a fluid at rest.

Velocity pressure is the kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity.

Total pressure is the algebraic sum of the velocity pressure and the static pressure with due regard to sign.

Total Pressure = ± Static Pressure + Velocity Pressure

Example: To measure air volume from cooler
Duct 38″ dia. = 7.876 sq. ft.
Temp. D.B. = 100°
W.B. = 80°
P = Psychrometric Chart
= .069 lb./ft.^{3}

After taking traverse, average velocity = 3842 fpm @ standard conditions = .92 VP or taking the average of the square root of the VP, squared = .92.

Reading psychrometric chart at intersection of 80° wet and 100° dry bulb, you read 14.5 cu. ft./lb. The reciprocal of this is the density .069 lb./ft.^{3}

$$\text{Velocity} = 1096.5 \sqrt{\frac{AP}{p}}$$

AP = Velocity pressure

$$\text{Velocity} = 1096.5 \sqrt{\frac{.92}{.069}} = 4060/\text{min.}$$

p = Density

$$Q = A \times V$$

$$Q = 7.87 \times 4060 = 31{,}600 \text{ cfm @ } 100^\circ \text{ F}$$

Q = Cubic feet per minute
A = Area of pipe square feet
V = Velocity in feet per minute

To check the prime air mover to see if it's operating properly, check the volume, total pressure, and horsepower on the fan curve or chart.

All fan curves and charts are published at standard conditions, 70° F, 29.92″ Hg barometric pressure. When using the charts or curves, measured pressures and horsepower must be corrected back to standard conditions by multiplying by the absolute temperature ratio.

HP @ Elevated conditions

$$\text{HP measured @ } 100^\circ\text{F} \times \frac{460 + 100}{460 + 70} \times \frac{560}{530} = \text{HP @ } 70^\circ \text{ F}$$

SP or TP @ elevated conditions

$$\text{SP} \times \frac{460 + 100}{460 + 70} = \text{Pressure @ } 70^\circ \text{ F}$$

All fan manufacturers who are members of the N.A.F.M. will provide you with a curve drawn for a constant RPM and usually the RPM for which your fan is selected.

Using fan static pressure, horsepower, and air volume, you can find your operating point on the curve.

Fan static pressure = Fan total pressure – velocity pressure (outlet)

All fan manufacturers use as the ordinate fan static pressure.

Total pressure of the system = T_p system = T_p inlet + T_p outlet neglecting the signs

$$\left.\begin{array}{l} T_p \text{ inlet} = -Spi + Vpi \\ T_p \text{ outlet} = Spo + Vpo \end{array}\right)$$

After the initial readings have been taken and for some reason such as system change, too much material loss for process, etc., the following laws can be used to predict a new operating point.

$$\begin{array}{l} CFM_2 \text{ x } RPM \\ CFM \text{ x } SP \quad \text{or } TP \\ CFM_2 \text{ x } HP \end{array} \qquad \frac{CFM_1}{CFM_2} = \frac{RPM_1}{RPM_2}$$

When making a speed change, you can, by using the above formula, predict the new CFM, TP, and required HP.

For rapid estimate of exhaust volumes or for estimating CFM available for a given motor size, the equation for brake horsepower can be used:

$$BHP = \frac{CFM \text{ x } TP}{6356 \text{ x } ME}$$

Me = Mechanical efficiency
Normally ME around .60 to .65 for industrial exhausters

1. Locate fan or clean air side of dust collector if possible to minimize erosion, abrasion, and buildup.
2. Eliminate elbows, inlet and outlet obstruction, sharp elbows at fan inlet will seriously reduce the volume discharged.
3. Fan rotation. Fans running backward will move a fraction of their rated capacity and many times such incorrect operation often goes unnoticed.

In this discussion, time would not permit derivation of formula, for further study, see Buffalo Forge Fan Engr., or AAF Physics of Air Handbook, or the American Conference of Governmental Industrial Hygienists bulletin.

DISCUSSION

I might put a plug in here. For many people who are interested in the air flow, who are apt to deal with air flow measurements, doing duct work design, there is an awfully good manual published by the American Conference of Governmental and Industrial Hygienists done in cooperation with Michigan State Department of Health and also the University of Michigan at Lansing. If you are interested in measuring air flow, most of the data I have are taken from this book, which is available from the American Conference of Governmental and Industrial Hygienists. I think it cost $4. It also gives you maximum allowable concentrations of material that you can put into the atmosphere according to hygienists' standards.

Many times it is necessary to measure the air flow from your dryer, cooler, and ammoniator or from some general ventilation system. When you purchase a dryer or cooler, generally you obtain a fan or an air prime mover. Sometimes on your own you ask the dryer manufacturer or the cooler manufacturer to tell you the horsepower for the air volume you want to move, and then you purchase the fan.

After this fan or air prime mover is placed in the plant, your dryer is operating, the plant is up to production, how many times is the volume checked to see that it is in accordance with design conditions, what the dryer manufacturer tells you you should be handling? Is it done very often or is it ever done?

Many times after your plant is in operation for several years your duct work may corrode out, may become plugged. You send your maintenance men or millwrights out, and they cut the duct work out and put new duct work in or for various reasons they will change the system. Do you ever go back and check your air flow to see that you are not getting more air resistance? If you reduce the resistance, you will get more air flow per r.p.m. If you increase the resistance, you reduce your air flow. This leads to improper drying of your product or, if you carry over too much product to your cyclones, it can be expensive to you.

The real heart of the dryer or the cooler is actually the air prime mover. Without the air prime mover you can't dry or cool your material.

On the Pitot tube which I showed you a minute ago, you have a static tap and a total pressure tap. You connect those to your "U" gauge. When you do that you are measuring the difference in the total pressure and the static pressure, which is the resultant velocity pressure.

When you do that you also have to take the temperature reading. In other words, you must get the humid volume of the air, the pounds per cubic foot. You do that by taking a dry and wet bulb reading. You go into this psychometric chart, which is available in many magazines or trade books, and you find the volume that your operating conditions show. In other words, I selected as an example a cooler with a 100 degrees dry bulb and an 80 degrees wet bulb. On the psychometric chart the pounds per cubic foot come up to .069, just substituting in the equation.

You have the Pitot tube and you measure the velocity pressure. You can take this book and by an easy, simple method, as you measure a number, you will measure higher than that, but I am trying to give you an average. Then you substitute it in an equation. This is beyond the point of trying to derive the equations, which will be published in the Proceedings. Velocity is equal to the square root of 1096 divided by rho. Then you substitute your velocity pressure into your equation and come up with a velocity, which is a simple thing to do. You can slide-rule it out really fast. Then you have the velocity in your duct at the temperature at which you are operating. You substitute in another equation, which is c.f.m. is equal to the area times the velocity. Then you come up with your volume and temperature.

You have got all these data. You have the air flow now. We have gone into some of the means, not very well, but we have gone into the means of doing it. You have these conditions and your dryer is operating at this fixed point. You have the r.p.m. and the c.f.m., and it would be very advisable to have a horsepower reading. If you want to reduce the air volume you must reduce the r.p.m. By using a 3-set rule, called fan logs, you can predict any point that you want to operate. The fan logs or the c.f.m. are directly proportional to the r.p.m. The c.f.m. squared is directly proportional to the static pressure. The c.f.m. cubed is proportional to horsepower.

There is only one thing you have to remember. In doing this the fan manufacturers have confused the whole thing as much as we could because we didn't teach people total pressure. We have taught them fan static pressure. I have a paper here in which we go into what total pressure is and what static pressure is, but there isn't much sense in my reading it off. You have to be careful and see what your curves are plotted in. Fan static pressure is the total pressure minus the velocity pressure at the outlet. You have to be careful the data you get when you go into a curve is the correct data to use.

The other thing is, all curves, as you probably know, are calculated at standard conditions, which means 70 degrees Fahrenheit, 50 per cent relative humidity, and 29.92 barometric pressure. When you get these data you must correlate it and take it back and correct it to these conditions, or if you try to check it against a chart you would just go out of your mind. You can't do it. So many people take the data and go in the chart but don't correct it.

All this leads up to one thing. When you finish with all these things and you come up at the end of the year, if you can save yourself one, two, three, four, or five horsepower by sizing your duct work correctly, by operating your fan at peak efficiency, you are saving yourself anywhere from 30 to 100 hours per horsepower. It is not much trouble to check these things out or to get one of your young engineers to check them out. I am sorry we do not have the time to go really into writing the equations down and going into it in a little more detail.

Question No. 7—What Are the Important Basic Principles to be Considered in the Selection of a New Granulation Plant?

Joe C. Sharp

FOR this discussion, it is assumed that principles of granulation are understood. That, for example, some grades require auxiliary heat and liquid phase other than that supplied from the reaction of the ingredients which go to make up the most economical formula. That other grades require heat and liquid phase generated from the reaction of the ingredients in the formula to be diluted or removed in order to control granulation. In still other grades, the temperature and liquid phase are in about the correct balance for optimum granulation.

Generally, grades in all three of the above categories have to be produced to meet the demand in most locations. The relative tonnage of grades that fall in each category will determine the optimum method of bringing about the proper heat and liquid phase balance.

For grades that require auxiliary heat and liquid phase, there are two ways that are used extensively. One is the use of steam. The other is the use of heat generated when sulfuric acid is reacted with ammonia even though the ammonia in the most economical formula does not exceed the amount that can be absorbed by the superphosphates.

When the demand for grades that require auxiliary heat is great enough, steam generally costs about one-tenth as much as sulfuric acid per ton of finished product. When the demand for such grades is small, the payout on the steam plant may never be realized.

For grades where the lowest cost formula produces too much heat and liquid phase, provision must be made to recycle fines in order to reduce the temperature and to lower the liquid phase. On the other hand, temperature and liquid phase may be reduced by replacing liquids in the formula with solids.

On some grades, 5 to 10 per cent of the formula cost may be saved by controlling temperature and liquid phase by recycle. This method of controlling temperature and liquid phase increases the screening and drying capacity required and, in addition, extra equipment must be employed to handle the recycle for such control. If only a small tonnage of such grades is required, the equipment payoff may never be realized.

To make another generalization, the trend has been steadily toward higher concentration because of several factors. One, it costs just as much freight on a ton of fertilizer that contains 20 units of plant food as it does for a ton of fertilizer that contains 40 or more units of plant food and freight rates continue to increase regularly. Two, other fixed costs such as bags and handling, tend to increase the unit cost on low analysis fertilizer faster than it does on high analysis fertilizers.

Greater concentration calls for more liquid materials, like phosphoric acid and nitrogen solutions, consequently equipment that is not designed to cope with high liquid phase will likely become obsolete before it can be amortized.

Metering and weighing equipment should be accurate. Corner-cutting causes consternation in this category. Inferior equipment causes off-grade product which is costly because of penalties on deficiencies, overages on material or plant food being given away. In addition to direct money loss, the company's reputation is jeopardized.

On the other hand, the best equipment available does not insure efficient operation. The human element must be reckoned with. Inefficient personnel will, however, be able to get good results out of accurate equipment, whereas not even efficient personnel will be able to get good results with poor equipment.

The plant should be designed to meet present needs with ample space to install additional equipment as needed.

To follow the process flow from raw materials to finished product, dry raw materials should be ground to pass a 10 mesh screen and mixed thoroughly. Anhydrous ammonia and solution, when used in combination as a source of nitrogen, should enter the ammoniator or pug mill through a common sparger. To insure even flow through the flow meters, each liquid should have a minimum pressure of 60 p.s.i.g. at the respective flow meters. Water should also have at least 60 pounds pressure if it is to be mixed with anhydrous ammonia. Downstream from the flow meters, the free liquids flow into a specially designed mixing pipe and then through the sparger into the ammoniator or pug mill.

Acids that are used for the purpose of increasing temperature and liquid phase should be added to the ammoniator, or pug mill, through an acid sparger. Never attempt to bring ammonia or nitrogen solutions and acid together inside the pipe or sparger. If both sulfuric acid and phosphoric acid are used, they may be mixed downstream from the flow meters ahead of a common sparger.

When sulfuric acid is used solely for the purpose of neutralizing ammonia in solutions, the two materials in stoichiometric amounts should be brought together downstream from the flow meters in a preneutralizer tank. Bringing acid and solution together in this fashion permits higher temperatures without suffering a nitrogen loss. The evaporation of more water results, which results in lowering the liquid phase and the over-all temperature. From the open top preneutralizer tank, the amomnium sulfate and ammonium nitrate slurry formed in the tank flows into the ammoniator, or pug mill, through an overflow pipe by gravity. Mixes of phosphoric and sulfuric acid may also be added to the preneutralizer.

Solid raw materials and fines recycle join the liquids in the ammoniator or pug mill where proper conditions for agglomeration must be maintained. The ammoniator or pug mill must be sized to handle recycle, as well as raw material input.

From the ammoniator or pug mill the material flows by gravity to the dryer. In most plants, the dryer is under-designed. The mechanical condition of the finished product is dependent on the moisture content more than any other one thing.

Many plants, in an effort to get the moisture content low enough to insure good mechanical condition, increase the dryer temperature to the point where heat sensitive material decomposes, resulting in plant food loss and air pollution. Some dryers are even designed so that the burner flame actually comes in contact with the material. This should never be done.

The material from the dryer should be elevated and classified. The fines should flow into a recycle hopper to be fed back into the system as needed. The oversize should flow to a crusher and back into the dryer. Oversized particles are wet on the inside and should not be returned to the screen until the crushed material has passed through the dryer a second time. The onsize should flow to the cooler.

The screen should also be of sufficient capacity to handle recycle, as well as finished product. Poor screening frequently is responsible for fines getting into the finished product. Also, it can cause the system to get off balance.

The cooler should be of sufficient capacity to send the finished product to storage below 120°F.

Grades containing more than 300 pounds of ammonium nitrate should be coated with diatomaceous earth to prevent caking.

Summary

Steam is the most economical source of auxiliary heat and liquid phase when sufficient volume of grades are produced.

Recycle is the most economical means of controlling excess heat and liquid phase.

A preneutralizer also helps control over-all heat and liquid phase, as well as reducing nitrogen losses.

Drying is often a bottleneck and should have ample capacity provided. Never have the flame come in contact with the material to be dried.

Screening should be done at the end of the dryer and sufficient capacity provided.

The product should be cooled below 120°F. before going to storage.

Grades containing more than 300 pounds of ammonium nitrate should be coated with diatomaceous earth.

DISCUSSION

Monitor, J. E. Reynolds.

Monitor Reynolds: Charles Major, of the Spencer Chemical Company, will discuss this question.

Mr. Charles J. Major: This is a very broad subject, and for this discussion I would like to assume that everyone is familiar with the principles of granulation—that, for example, some grades of fertilizer require auxiliary heat and liquid phase other than that supplied by the reaction of the ingredients which go to make up the most economical formula; that other grades require that the heat and liquid phase be diluted or removed for the most successful granulation; that still other grades are in an almost correct balance for best granulation. Generally, all three of these grades will have to be produced in a location to meet customer demand. The relative tonnages or percentages of each of these grades will determine the optimum method or the best method of bringing about the proper heat and liquid phase balance for granulation.

For grades which require auxiliary heat and liquid phase, there are two ways in the fertilizer industry that are used extensively. One is steam. The other is the use of heat generated by the reaction of sulfuric acid and ammonia in ammonia solution, even though the total amount of ammonia in the formula does not exceed that which can be absorbed by the superphosphate.

When the demand for grades that require auxiliary heat is great enough, steam generally costs about one-tenth as much as sulfuric acid per ton of finished product. When the demand for these grades is small, very often the cost of the steam plant cannot be realized, and sulfuric acid would be favored in this condition.

For grades where the lowest formula cost produces too much heat and liquid phase, provision must be made to recycle fines in order to dilute the excess heat and liquid. On the other hand, temperature and liquid phase may be controlled by substituting solids for liquids.

On some grades, 5 to 10 per cent of the formula cost may be saved by controlling temperature and liquid phase with recycle as opposed to substituting liquids with solids.

This method of controlling liquid phase with recycle increases the screening and drying capacity that will be required and, in addition, extra equipment must be employed to handle this recycle. If only a small tonnage of these high liquid phase fertilizers is in demand in this location, the additional expense would have to be weighed against cost per ton before you would go in this direction.

The trend has been steadily towards higher analysis fertilizers for several reasons. One, the cost on freight is the same on a fertilizer with 20 units of plant food as it is on fertilizers with 40 units of plant food. Furthermore, fixed costs such as bagging and handling, tend to increase the unit cost on low analysis fertilizers faster than on high analysis fertilizers. This greater concentration of plant food requires more liquid materials such as phosphoric acid and nitrogen solution to be used. Consequently, fertilizer equipment that is purchased which is not designed to cope with these high liquid phase materials will likely become obsolete before it is amortized.

Metering and weighing equipment should be accurate. Inferior equipment causes offgrade product which is costly from penalties because of low analysis or plant food being given away. In addition, inaccurate equipment sometimes jeopardizes the company's reputation. On the other hand, the best equipment available does not insure efficient operation. The human element must be reckoned with. Inefficient personnel will, however, be able to get good results out of accurate equipment, whereas even efficient personnel will not be able to get good results from poor equipment.

To follow the process flow from raw materials to finished product, dry solids should be ground to pass a 10 mesh screen and thoroughly mixed. Anhydrous ammonia in solution when used in combination as a source of nitrogen should enter the ammoniator or pug mill through a common sparger to insure an even flow of ammonia and solutions. A minimum of 60 pounds per square inch gauge at the respective flow meters should be maintained. Water, if it is to be mixed with anhydrous ammonia, should likewise have 60 pounds per square gauge. Downstream from the flow meters the free liquids flow into an especially designed mixing pipe and then to a sparger in the ammoniator or pug mill. If it is used for the purpose of increasing temperature, liquid phase alone should be added to the ammoniator through a separate acid sparger. If both sulfuric acid and phosphoric acid are used, they may be mixed together downstream from the flow meters and entered through a common sparger. When sulfuric acid is used solely for the purpose of nuetralizing excess ammonia in ammonia solutions, the two metered materials should be brought together downstream from the flow meters in an open top pre-neutralizer tank.

Bringing the acid and solutions together in this fashion permits higher temperatures without suffering nitrogen losses. The evaporation of this water results in a lowering of the liquid phase and an over-all dilution of temperature.

The ammonium nitrate, sulfate of ammonia slurry flows by gravity into the ammoniator. Solid raw materials and recycle join the liquids in the ammoniator or pug mill, where proper conditions for granulation are maintained. The ammoniator or pug mill must be sized to handle not only the input of raw materials but also the recycle.

From the ammoniator or pug mill the material flows directly to the dryer. The dryer should be ample to handle not only the input raw materials but also the necessary recycle to control liquid phase in the ammoniator.

From the dryer the material would be elevated and screened. The fines should flow into a recycle hopper to be fed back into the system as needed. The over-size should flow to a crusher and be returned to the dryer. Over-size particles are wet inside and should not be returned to the screen until they have been crushed and passed through the dryer the second time. On-size should flow to the cooler.

The screen should also be of sufficient capacity to handle recycle as well as product. The cooler should be of sufficient capacity to send the finished product to storage below 120 degrees Fahrenheit.

Grades containing more than 300 pounds of ammonium nitrate should be coated to prevent caking.

Mr. L. M. Leach (Indiana Farm Bureau): I would like to add just a comment, that when we get into the liquid phase which Charles Major was talking about a while ago, if it ever hits the screen you have had it, because it is mighty hard to screen if it is too wet.

At Indianapolis, when we put in our granulation system we did dry screen and then cool. We put in three granulation systems since then and they are all dried, cooled, and then screened. I will throw my chances on drying, cooling, and then screening.

Question No. 8—Can We Save on Operating Costs and Have a Good Condition Material If We Screened Out Only the Fines Finer Than 24 or 28 Mesh.

F. T. Nielsson

At a given moisture content, caking of mixed fertilizers is a function of the formula, and the amount of contact among the fertilizer particles. If the moisture content is low enough for the formula you are using, 24 or 28 mesh particles will not affect condition appreciably.

Figure I shows an idealized

view of contact among uniformly sized particles, where particle "A" has six contact points. Figure 2 shows a similar view of contact where the particles vary in size. Particle "B" has eight contact points.

The condition shown in Figure 2 would yield a stronger bond and therefore more caking under the same factors of formula and moisture content than would the condition shown in Figure 1. Good concrete requires an aggregate of wide size distribution.

Moisture allows dissolved salts to creep to the outside of the particles where the salts can recrystallize as the temperature changes. The higher the soluble salt content (ammonium nitrate, muriate, diammonium phosphate etc.) the greater the caking tendency at a given moisture content.

At low moisture contents, no salt solution is present, no salt migration occurs, and caking is minimized. I have seen tests of 5-10-10 conventional fertilizer (all minus 20 mesh) dried artificially to a 1% moisture content with no caking after being stored in bags 10 high.

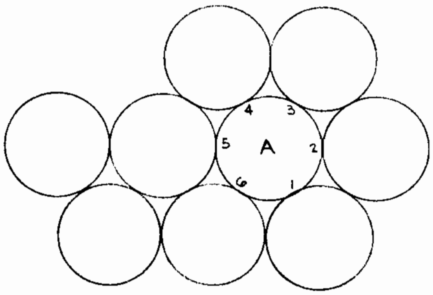


FIGURE 1
UNIFORMLY SIZED PARTICLES

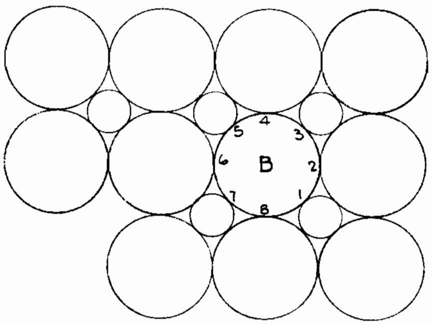


FIGURE 2
VARIABLY SIZED PARTICLES

Therefore, if the moisture content is low enough for the formula you are using 24 or 28 mesh particles will not affect condition appreciably.

The wider the particle size spread of the product, the less the recycle needed to meet specifications. The less the recycle, the higher the production rate. Usually, an increase in production rate lowers production costs.

However, there are some grades like 12-12-12 or 14-14-14 where the use of high recycle permits the use of all nitrogen from solution. In such a case, high recycle means a less expensive formula.

On the other hand with 5-20-20 and 6-24-24, high recycle requires more heat and moisture for granulation. With such grades, the lower the recycle, the less expensive the formula.

Each plant has to decide for itself how much it is willing to pay for a pretty product.

DISCUSSION

F. T. Nielsson: Can we save on operating costs and have a good condition material if we screened out only the fines finer than 24 or 28 mesh?

I think generally that this is fairly simple; that at a given moisture content the caking of mixed fertilizers is a function of the formula and the amount of contact area among the various particles. So generally we can say if the moisture content is low enough for the formula you are using, 24 or 28 mesh particles will not affect the condition appreciably.

(At blackboard) To clarify that, assume that you have uniform size particles. This particle here is contacting, let us say in this case, at four places, so we have four contact areas. If you want to put the fines in the product you can imagine that the fines would fill in these spaces. If that happens, you pick up more contact area. So, simply, if you have more fines you have more contact area, and we know that in good concrete you like to have particles of various size. Of course, concrete is something which normally is wet. So if you don't want to make concrete, you should have things uniform. That is one way of looking at it.

Moisture allows the dissolved salts in the formula to creep to the outside of the particles, and there on the outside of the particles the salts as they creep to the outside recrystallize at these spaces, and as they recrystallize they make cement particles. So the higher the soluble salt content — ammonium nitrate, muriate, diammonium phosphate— the greater the caking tendency at a given moisture content. If you remember, this is all at a given moisture content.

If the moisture content is low enough, no salt solution is present, no salt migration occurs, and you don't have any caking. I have seen tests of 5-10-10 conventional fertilizer, regular powdered fertilizer, all minus 20 mesh, dried in a dryer just as a test down to one per cent moisture, and there was no caking when that stuff was stored ten bags high for six weeks. So I personally feel sure that you can run any powdered fertilizer through a dryer and won't get caking. You don't have to granulate to stop caking. All you have to do is dry it.

If you put powdered fertilizer through a dryer, of course it will all go up through the dust collector. That doesn't alter the fact that if the stuff is dry enough it won't cake. If we dry it and we have fines in there, we don't affect the condition.

From the other angle, from the cost angle, the wider the particle size, the less the recycle you have to add to meet the specifications. Normally, the less the recycle, the higher the production rate. Usually an increase in production rate lowers production costs.

On the other hand, there are some grades like 12-12-12 or 14-14-14 where the use of higher recycle permits the use of all nitrogen from solution. In those cases, higher recycle leads to a less expensive formula.

On the other hand, with 5-20-20 or 6-24-24, higher recycle requires more heat and moisture for granulation. So with such grades, the lower the recycle, the less expensive the formula.

You have a choice here as to

how much money you want to spend to make a pretty looking product. That is in essence the meat of the whole problem. If you want to make it look pretty, you have to spend money for it. If you don't care what it looks like, it doesn't cost much to make it. In either case, whether it is pretty or not, if you dry it you won't have caking.

Mr. Carl P. Schumaker (Monsanto Chemical Company): One thing which I think is of interest in Mr. Nielsson's presentation is the effects he described represented by the use of cold recycle rather than hot recycle, which seems to be coming into common use based on the discussion of the previous paper where hot recycle was the way that that plant was set up.

Question No. 9—What Are the Advantages and Disadvantages of Controlling All Recycle Portions Returned to the Ammoniator—Granulator?

Rodger C. Smith

THE question refers to that material passing the lower deck of the classification screen, I am sure that we all understand. The coarse fraction remaining on the upper screen normally passes without adjustment of flow to mill for reduction of granule size and return to the flow of material ahead of the classification screen.

The equipment required is very nominal and virtually no labor is required other than normal supervision. Essentially what is required is a hopper having capacity of about 25% the hourly production rate and a method of at least rough control of flow rate from the hopper. The hopper can be located immediately beneath the classification screen or otherwise intermediate between the screen and the flow of material to the ammoniator-granulator. With batch mixing, a satisfactory arrangement is to use a bin above the weigh hopper into which a uniform amount of the fine recycle can be weighed in addition to the dry ingredients. Some means of rough control of the rate of flow from the hopper in a continuous system is necessary, say within 5% accuracy, and also have provision for easy adjustment of flow rate. A recycle of 30% is 600 pounds per ton of production. Control of the fines flow rate within 5% is within 30 pounds per ton of production. Vibrating feeders commonly available at low cost or a simple gate device is satisfactory.

This simple addition to a granulation unit can aid operating personnel, reduce costs and improve product far beyond the added cost of installation, particularly during the early stages of operating the unit or when making major adjustments in formulation. Once the formulation and equipment operation is well stabilized, there is much less variation in rate of producing the fine fraction.

The problem is that some circumstance causes an excess accumulation of fines, such as a new formula, a different lot of superphosphate or other material having different moisture content or particle size thus changing the degree of wetness, or a holdup in the flow of ingredients to the process temporarily increases the proportion of recycle to dry and liquid ingredients. The immediate result is that the fertilizer mass becomes dryer, the range of granule size becomes smaller and the proportion of fines produced increases. Unless checked, the cumulative fines and overload on the whole system can cause a shutdown. The purpose of the hopper and method of controlled return rate gives the necessary time to adjust the formula, to add water or make other change necessary without an excess accumulation.

The condition causing fines has to be adjusted to, but time is provided and frantic moments avoided. A temporary condition causing the mass to dry can cause a surging effect, wherein a dry condition at one time, though adjusted to, will cause a dry condition in the mixer several minutes later when the effect of fines produced returns again to the mixer. Without a means of leveling off the rate of fines return, a difficult situation exists for the operators.

There is not suggested the removal of fines from the system, only a controlled rate of return. The improved product and operation far outweigh the nominal investment required.

A. Henderson

(1) We assume that "all recycle" means recycle material from two sources:

  (a) material from air handling system.

  (b) material from screening system.

(2) We can say that "control" is the key word associated with any *good granular system*. Further, that it is absolutely essential to control all major factors. Some regard recycle as the most important single factor. Hence, the conclusion that it is absolutely necessary to control all recycle. This statement sounds true, but as many know, it isn't. The fact is, that some plants do a good job without means of controlling recycle. If, however, we specify that a *good granular system* is a near perfect system, then the above statement becomes more significant.

(3) I heard somebody say once that the efficiency of any system is a measure of its means of "staying out of trouble."

Perhaps too many of us regard efficiency as a means of "getting" out of trouble, rather than "staying" out of trouble. For lack of a better reason, I believe this concept to be the principal advantage of controlling all recycle. Moreover, if considerable flexibility is required and a very closely sized product is to be made, more controls are necessary.

(4) We cannot speak for all plants and, therefore, we must confine our discussion to a reasonably well designed plant. In such a plant the cost of controlling recycle should not be more than $2,000, and probably less. All that is required is a hopper, some type feeder, one of several chutes, and perhaps a screw conveyor. The question now resolves to control of "all recycle." First, assume that the principal source of recycle material is that produced by the screening system. We have a fines hopper and a feeder which delivers the material from fines hopper back to the ammoniator at a controlled rate. Now the only material that we have remaining is material from the dust system. This material is more troublesome to handle than regular fines, because it is hot, damp, and naturally has great tendency to cake, bridge, and bind screens. We can introduce this material directly into the ammoniator as it is discharged from the cyclones.

This is not controlled; however, since the material is uniform and discharged at a reasonably constant rate, it is not a large variable. We can deliver the material from the cyclones to the ammoniator by a screw conveyor. This is partial control and serves to even out the flow. Finally, we can deliver the dust back to the screening system, where it is screened and becomes part of the regular cycle. This, of course, is complete control of all recycle. The problem with this last step is that the hot, damp, dust places greater load on the screens, and even for short shut-down periods causes caking and bridging in the fines hopper.

(5) It has been our experience that recycle is not a good means of control execpt to initially establish equilibrium conditions or to get on formula. Then we make every effort to keep recycle constant. This, of course, is controlling it's rate of feed. We believe that it is not a good means of control because of the following reasons.

(1) Material is variable.

(2) Reacts to changes slower than H_2SO_4, steam, or H_2O.

(3) Overloads equipment when used excessively.

(4) Changes volume relationship in ammoniator.

(6) In conclusion, we believe that controlling "all recycle" at least to some extent is a most helpful factor. We feel that it is better to partially control material from the dust system by delivering to the ammoniator by screw conveyor, as against delivering it back to the screen system. Reasons for this have been previously discussed. We feel that as product quality continues to improve, that controlling recycle will become standard practice.

Question No. 10—Should I Use a Batch or Continuous Production System?

Rodger C. Smith

SINCE the beginning of the study of granulation of mixed fertilizer, a major question has concerned how to provide uniform conditions for granulation—that is, uniformity of temperature of fertilizer entering the dryer, of the amount of liquid phase of the fertilizer discharging from the mixer or entering the dryer, uniformity of quantity of fertilizer at any given point along the length of the dryer or cooler and finally uniform load on the classification equipment.

The importance of uniform temperature, moisture and load conditions to granulation has been described by many Round Table participants. It follows, therefore, that a satisfactory continuous method of mixing overcomes a major problem in granulation. Any attempts to develop a feeder between batch mixer and dryer which would maintain a fertilizer mass of uniform granulating characteristics have been only partially successful.

With a recognition of these basic principles coinciding with the development of the T.V.A. continuous ammoniator, it is understandable that the vast majority of granulation units installed during the past four years include this ammoniator-granulator.

The question, I believe, is not between the basic principles of batch versus continuous process of granulation. The question is between the two methods at their present stage of development. Either within or out of the fertilizer industry, batch mixing is much older. We are comparing two methods of differing stages of development and of widely different background of experience by technical or operating personnel in the industry.

The result of appraisal of the two processes using equipment now available can favor continuous or batch depending on some conditions affecting an individual plant —such as plant size, amount of fertilizer granulated, existing equipment and space limitations if a conversion and technical personnel available.

Now, let us look at a few cost factors:

The investment is somewhat

larger for continuous mixing than batch equipment. Unless individual feeders are installed for each ingredient, a premixer is necessary. The dry ingredient feeder in advance of ammoniator plus the meters for ammonia or solution and for acid are more costly than volumetric measuring tanks. In some installations an additional elevator is required with continuous method. The net increased investment can be as much as $25,000. On an annual tonnage of 10,000 tons granulated, this is about 25 cents per ton but on 25,000 tons, it is only about a dime.

Electricity or labor cost is very similar, not usually enough to be a factor. The premixer can be operated using air by the weighman or by automatic device.

Delays during the "Shakedown cruise" or later with the continuous method are largely related to unfamiliarity with the characteristics of new equipment, such as feeder, meters, sparger pipes, scraper, and any control equipment installed. These are integral parts of a continuous process. Information is sometimes scanty on the application of this exquipment to fertilizer use. The problems and delays can at times be exasperating, although not significantly affecting costs.

The major difference in the economics of these two methods is in formulation resulting from greater ammonia retention with the continuous ammoniator, particularly with high nitrogen grades toward which there is a trend in usage. With a 10-10-10 or 12-12-12 the nitrogen loss can be maintained at about 0.10 unit in a continuous ammoniator of known proper design whereas the loss in a batch mixer with a similar formula is approximately 0.60-0.75 units. The difference is about $0.80 per ton—a significant figure. If fume control equipment has to be installed that difference can increase substantially.

With a small plant and if not concerned with fume control for wide nitrogen to phosphorus grades, a batch mixer is satisfactory, but for large tonnages particularly of high nitrogen grades the per ton savings and operating performance justify the added investment and information. If in a congested area, a continuous ammoniator is now the most economical way to reduce gaseous effluent. Added technical developments such as preneutralization and added operating experience will most likely increase the relative merits of continuous mixing.

T. R. Schmalz

WITHOUT knowing more of the particulars relating to this question, the first answer would be to use a continuous system.

Specific details of the circumstances prompting this question might have considerable bearing on the answer. If starting from scratch to build a granulating plant, initial cost of equipment would probably be the same for batching as continuous.

The advantages of formulation flexibility, recycle handling, control and ease of operation which continuous systems have over the batching operation makes the continuous much more desirable, in my estimation. Tonnage rates required would also influence such a decision, 20- or 30-ton per hour plants would be more economical to run as continuous plants than as batch plants.

The thing to keep in mind, I should think, is that the ammoniation equipment is all that is in question, since the same equipment would be used from this point on in either case.

Question No. 11 — Indicate Some Relationships Between Equipment Size, Rate of Production Per Hour and Per Ton Cost of Production.

Grant C. Marburger

THE per ton cost of production increases as the production rate decreases. Henry Ford proved this principle many years ago in the concept of mass production. In fertilizer manufacture, the cost of raw materials must be separated from all other production costs to obtain a realistic picture, because formulation can affect production rates in some grades under some instances. When this occasion arises, the principle of mass production must be varied. The grade to be produced and other considerations of the case must be given individual attention to arrive at an economic balance; it cannot be done by general principles alone. The variables are a function of the equipment available, the formula, and the delivered costs of raw materials at that location.

One example might be cited: In low nitrogen high phosphate ratios, such as 4-16-16 or 5-20-20, there are a number of variables that can be used to create the liquid phase necessary to achieve granulation. Water is one of them. Others include sulfuric acid, steam, phosphoric acid and ammonium nitrate or other soluble salts. If water is utilized rather heavily to achieve granulation, the dryer capacity in a given plant might be insufficient to allow as high a production rate as would be possible with less water and more sulfuric acid in the formula. But the additional cost of sulfuric acid would have to be balanced against the higher production rate achieved.

Very little more can be said about the per ton cost of production in a discussion designed to cover basic principles only. An economic study, based on specific technology, is the next step and such a presentation has not been prepared for the generalizations in this discussion.

It is difficult to be definite on relationships between equipment size and rate of production. Frequently in the past, small production plants have included another factor, lower quality product, so experience is lacking in an accurate comparison of the equipment sizes that are necessary to produce the same quality granule at different rates of production.

In any plant, small or large, the question can be asked "What is the first bottleneck that will limit its production rate?" The answer to this question frequently is revealing. In the past, the product screens have most frequently been the undersized item. This generally means that a large screen is needed, yet in some cases the plant's operation can be changed to correct wet material that is blinding the screen and lowering its capacity. A plant producing 10 tons per hour can purchase a smaller screen than one designed at 30 tons per hour.

In most plants the dryer is sized too small. The mechanical condition of the finished product is dependent on the moisture content more than any other one thing. When sufficient capacity occurs, compensation by increasing the dryer temperature decomposes heat sensitive materials which can cause plant food loss, caking of the dryer flights or, even more serious in some locations, the creation of fumes that become an air pollution nuisance. In the case of overheating X-O-X grades, decomposition will produce a fume dangerous to humans. Improperly designed flights will seriously limit capacity in both dryers and coolers; the cost of flights is small compared to the total costs of these vessels. The lessons that have been learned from the past would warn future plant designers against dryers too small for quality production, and coolers should be capable of sending the finished product to storage below 120°F.

Exact relationships between rate of production and the dimensions of drying and cooling vessels cannot be simplified to a single set of rules; the formulation practices used, the grades produced and the quality of product desired are some of the variables involved.

Undersized dust collection systems can affect production rates in areas concerned with air pollution. However, the size of the dryer and cooler will determine the volume of air to be handled by the cyclone dust collectors which, in turn, determines their sizes.

The continuous ammoniator-granulator cannot be materially varied in size to fit different rates of production. A minimum size is dictated by the necessity to handle a bed of material in proper physical condition and at the same time achieve ammoniation, mixing, and granule formation. Yet it is a rare case in today's granulation experience that this minimum sized vessel is too small for most production rates. It is possible that bottlenecks appear in most plants before the production capacity of the reactor has been reached, so the top capacity of ammoniator-granulators may be somewhat unknown. Because granulation is still an art that depends on an operator's visual control, an upper limit in production may be inherent to these physical limitations.

Raw materials should be crushed to pass a ten mesh screen if a six mesh top screen is used for finished product. A screen that can handle 40 tons per hour using a five mesh screen will have less capacity when changed to ten mesh. Generally speaking, however, raw material screens have not been undersized and their size can be varied directly for any production rate desired.

The use of steam in granulation plants is increasing for the production of grades that require auxiliary heat and liquid phase. The size of the steam plant is a direct function of the production rate desired. It can be calculated on the basis of 135-150 pounds of steam per ton of production, translated to boiler horsepower.

Many grades produced have an excess of heat and liquid phase which must be diluted or removed to control granulation. A controlled recycle system permits the use of fines to effect this control. When a surge hopper is used as part of the system, its size depends principally on the time of travel between the reactor and the hopper. Generally, ten to twelve tons of capacity will suffice; this can be lowered slightly or increased if conditions demand. This method of controlling temperature and liquid phase increases the screening capacity required in direct relation to the added load that the screen must carry.

In over-all, one or two precautions would be made to future plant designers from experiences learned in the past. First, define the grade before specifying the capacity of a plant. A guaranteed performance of 20 tons per hour means nothing unless the grade has been named and its formula specified. But of more importance, don't overlook the reduction in quality or the increase in formula cost that may be a part of increasing production rates or decreasing a plant's costs.

DISCUSSION

Mr. Paul Castagna: This question pertains to equipment in granulation, continuous process. The per ton cost of production increases as the production rate decreases. Henry Ford proved this principle many years ago in the concept of mass production. In fertilizer manufacture, the cost of raw materials must be separated from all other production costs to obtain a realistic picture, because formulation can affect production rates in some grades under some circumstances. When this occasion arises, the principle of mass production must be varied. The grade to be produced and other considerations of the case must be given individual attention. It cannot be done by general principles alone. The variables are a function of equipment available, formula, and the delivered cost of raw materials at that location.

One example might be cited. In low nitrogen-high phosphate ratios, such as 4-16-16 or 5-20-20, there are a number of variables which can be used to create the liquid phase necessary to achieve granulation. Water is one of them. Others include sulfuric acid, steam, phosphoric acid, ammonium nitrate or other soluble salts. If water is utilized rather heavily to achieve granulation, the dryer capacity in a given plant might be insufficient to allow as high a production rate as would be possible with less water and more sulfuric acid. The additional cost of sulfuric acid would have to be balanced against the higher production rate.

Very little more can be said about the per ton cost of production in a discussion designed to cover basic principles only.

An economic study based on specific technology is the next step, and no such generalization of this has been prepared to be presented here.

It is difficult to be definite on relationships between equipment size and rate of production. Frequently in the past, small plant production has included another factor: lower quality product. So experience is lacking for accurate comparison of the equipment sizes that are necessary to produce the same quality granule at different rates of production.

In any plant, small or large, the question can be asked: What is the first bottleneck which will limit the production rate? The answer to this question frequently is revealing. In the past the production screens have most frequently been the emphasized item. This generally means a larger screen is needed. Yet in some cases the plant's operation can be changed to correct wet material which is binding the screen and lowering its capacity. A plant producing ten tons per hour can purchase a smaller screen than one designed for 30 tons per hour.

In most plants the dryer size is too small. The mechanical condition of the finished product is dependent upon the moisture content more than any other one thing. When insufficient capacity occurs, there is compensation by increasing the dryer temperature, decomposing heat- sensitive materials, therefore causing plant food loss, or an air pollution nuisance. In the case of overheating, decomposition of grades like X-O-X will produce fumes dangerous to humans.

Improperly designed plants will seriously limit capacity in both dryers and coolers. The exact relationship between rate of production and the dimensions of drying and cooling vessels cannot be simplified to a single set of rules. The formulation, practices used, grades produced, quality of product desired, and other variables are involved.

Undersized dust collection systems can affect production rates in areas concerned with air pollution. However, the size of the dryer and cooler will determine the volume of air to be handled by the cyclone dust collector.

The continuous ammoniator-granulator cannot be materially varied in size to fit different rates of production. A minimum size is dictated by the necessity to handle a bed of material in proper physical condition and at the same time achieve ammoniation, mixing, and granular formation. Yet it is a rare case in today's granulation experience that this minimum sized vessel is too small for most production rates.

It is possible that bottlenecks appear in most plants before the production capacity has been reached.

So the top capacity of ammoniator-granulators may be somewhat unknown, because granulation is still an art and depends upon operator control. An upper limit in production may be inherent to these physical limitations.

Raw materials should be crushed to pass a 10 mesh screen if a 6 mesh top screen is used for finished product. A screen which can handle 40 tons per hour using 5 mesh will have less capacity when changed to 10 mesh. Generally speaking, however, raw material screens have not been undersized, and their size can be varied directly for any production rate desired.

The use of steam in granulating plants is increasing for the production of grades which require auxiliary heat in liquid phase. The size of the steam plant is a direct function of the production rate desired. It can be calculated on the basis of 135 to 150 pounds of steam per ton of production, transplanted to boiler horsepower.

Overall, one or two precautions would be made to future plant designers. First, to find the grade before specifying the capacity of the plant. A guaranteed performance of 20 tons per hour means nothing unless the grade has been named and its formula specified. But, of more importance, don't overlook the reduction of the quality or the increase in formula costs which may be a part of increasing production rates or decreasing the plant's cost.

Monitor Reynolds: Thank you.

A question?

Mr. Frank Doody (Darling & Co.) : Have you ever actually used a 10 mesh screen with raw materials?

Mr. Castagna: I have experienced it.

Mr. Doody: I mean on a production unit.

Mr. Castagna: Yes.

Mr. Doody: For any large tonnage runs?

Mr. Castagna: A tonnage rate of 20 or 25 tons per hour.

Mr. Doody: Through a 10 mesh screen?

Mr. Castagna: Yes.

Mr. Doody: We tried five, and we couldn't. It would block up the tonnage. We could not get the tonnage when we used five.

Mr. Castagna: This has been accomplished.

Mr. Doody: We didn't have too much luck with it.

Question No. 12—What Are the Advantages of Applying Suction to the Classification Screens. Cite Actual Experiences.

F. T. Nielsson

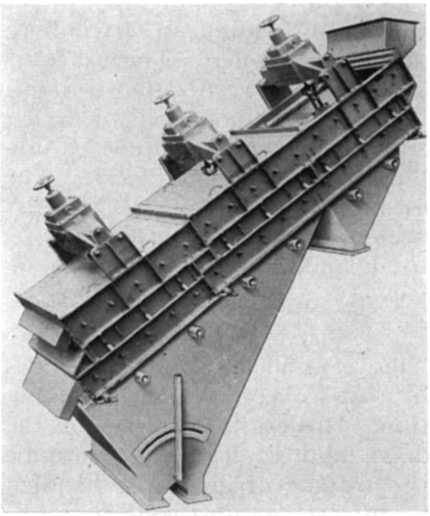
I BELIEVE the technique of supplying suction to classification screens at granular plants was first suggested by Wayne King of Tyler. As suggested by Wayne, and as applied at the plants I have seen, a series of ducts extend horizontally across the screens below the fine deck. Each duct has a slit on the underside. The ducts are connected to a header that in turn connects to the suction side of the drier or cooler exhaust system. The theory is that air will be sucked in through the screen decks and assist in cooling the product. In addition, some of the fine dust will be drawn off and not have to be handled by the fines screen, thereby keeping the screen area clean.

The idea may work fine if the header were connected to a specially designed dust system working at fairly high suction. However, in the installations I have seen, the suction is so weak that the dust collected in the transverse ducts settles out in the header and the connecting duct work, and the ducts soon stop up. After the operators clean the ducts a half dozen times, they decide the cost of cleaning is not worth the extra cooling they might obtain if the system were working and they stop cleaning the system.

Because, in my own experience, I have not seen a plant where the screen cooling system was in operable condition, I assume the degree of cooling in the average system, as currently designed, is not sufficient.

Wayne W. King

THE purpose of this paper is to clarify the necessary application of Air Suction to this process and explain the reasons for its success. For simplification we will outline the factors involved.



Application

Air suction to be properly functional and efficient must be applied to the material while it is falling through the screening surfaces and is in a thoroughly stratified condition.

To accomplish this task, complete uniformity of pull over the entire area and constant velocity is important. Proof of this is demonstrated by removing all of the dust covers and still maintaining a slight negative atmosphere within the entire screen body.

Details of construction show two 4″ I.D. pipes welded into the fines collecting hopper under each 5-foot length of screen. In each of these pipes there is a slot cut in the exact bottom and extending the full length of the pipe inside the hopper running across under the screening surface and at right angles to it.

The area of this slot is nearly equal to twice the area of the cross section of each pipe; constructed in this manner and by pulling from both ends of each pipe, a uniform down draft is created evenly across the entire inside width of the screen body.

Header Piping along the outside of the body connects into each end of all pipes as shown in the plan view of the slides. Succeeding piping should increase in size so as not to build up the velocity too greatly.

The volume of air required to do the best job varies widely, depending on the process, plant conditions, and desired conditions of product. The volume of air required through each pipe ranges from 250 to 850 C.F.M.

It is obvious that we want the largest portion of fines for recycle to discharge out the fines collecting hopper and as directly into the mix as possible to retain maximum temperature and best chemical control.

Too little air suction accelerates choke ups in piping and delivers to the cyclone only part of the extremely fine air float material.

Increasing the velocity and volume of air increases the particle size of the fines delivered to the cyclone.

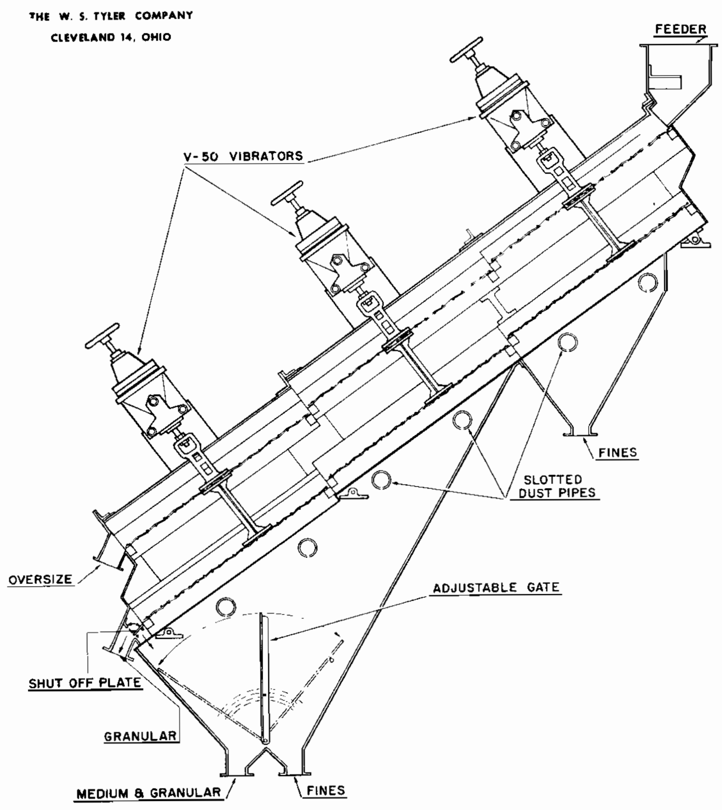
The coarser the material delivered to the cyclone (to a happy balance) decreases the caking tendency of the material in the cyclone for best operation. So a balance worked out on each installation offers a two fold basic advantage. Complete recovery of fines and minimumized caking.

It is impractical, although possible, to apply sufficient air suction to carry off all of the fines that pass through the finest screening surface of the classifier screen.

A separate fan, piping and cyclone works much better than a secondary system connected to the usually available system used for dryer and cooler.

Advantages and Benefits That Can Be Derived From a Proper Air Suction System

A. Complete recovery of all valuable fines not so generously



4' X 15' · 2 SURFACE · TYPE 38 · TANDEM HUM-MER ELECTRIC SCREEN

SK-1706 October 21, 1957

spread throughout the plant, from which deposits they are very difficult to reclaim.

B. Eliminate air float fines deposited on product and carried to storage area.

C. Remove the dust problem from the screen area and other work areas close by.

D. Reduce condensation of moisture on inside of elevator housing, screen body, and fines hopper which in turn will reduce caking of fine material in these housings.

E. The granular product or deck load over the second surface is reduced in temperature considerably, the oversize to a lesser degree and all of this heat energy is transferred to the fine material and ducts through which these fines travel to recycle.

F. This process offers an extra profit where the Classifier Hummer is installed in the flow between the dryer and cooler where condensation is such an obvious factor, and/or where only a cooler or dryer where only a dryer is used in the flow.

G. All of the benefits listed will in turn aid in the reduction of Preventative Maintenance required.

In conclusion, just as Morality is good business so is Good Housekeeping good business and profitable business.

DISCUSSION

Question: What are the advantages of applying suction to the classification screens? Cite actual experiences?

F. T. Nielsson:

It might be different, but where I have seen it, as I have said, the ducts stop up, the boys stop cleaning, the thing doesn't work, and once people don't use a system that is in there, all you can figure is that there can't be much to it.

Wayne W. King:

The advantages and benefits that can be derived from a proper air suction system:

Complete recovery of all valuable fines now so generously spread throughout the plant, from which deposits are very difficult to reclaim as such. We all know this.

Eliminate air flow fines deposited on the product and carried to storage area. They go over in static. With that mild air flow through there, they are reduced into the fines hopper. The huge portion of it goes directly past the pipe. All you are doing is creating a semi-negative in that fines hopper which pulls the air flow down, not up.

I hold no brief against putting a hood on there. It is like a man picking himself up by his bootstraps. You don't pull the air up or the fines up. It belongs down in the fines hopper, and that is why you should put your air suction at the bottom, not at the top.

You can remove the dust from the screen area and other work areas close by.

Here is the most important thing: You reduce the condensation of moisture on the inside of your elevator housing, on the inside of the screen body, and in the fines hopper, and it definitely reduces the caking of fine material in these housings. There is no question about that. It will do that.

The granular product or deck load over the second surface is reduced in temperature to some extent, the oversize to a much lesser degree.

Here comes your heat transfer. This is absolutely true, and we have measured it. All this heat energy is transferred to the fines material. It has to go some place. I am an engineer. I don't have any particular knowledge of heat other than I learned in school. But if you are taking the heat out of the intermediate, it has to go somewhere, and in this instance it definitely has to go into the fines. And it is my understanding that is what you want. Of course, that goes into the reycle.

This process offers an extra profit where the classifier is installed between the dryer and the cooler, where condensation is an obvious factor, and/or where only a cooler or a dryer is used in the flow.

Question No. 13—What Are The Principal Techniques of Ammoniation Which Contribute to Efficiency of Operation?

Since the amount of granulation achieved depends heavily on the ammoniator-granulator equipment, should not more attention be given to sparger design, location and performance toward this goal rather than toward ease of maintenance, lower initial cost and replaceability?

E. C. Perrine

MUCH more is now demanded of ammoniation than the simple economy in the small amount of ammonia that was being added to the formulae of yesterday. The economics are still so important that any change in processes or prices calls for a thorough re-appraisal of ammoniating practices. In addition to their influences on economy and the ability to hold a formula to grade, ammoniating techniques strongly influence the quality of pulverized fertilizer and even the ability to granulate, I said, in extreme cases. I will say now in many cases. Poor ammoniating techniques have also been associated with some flash fires in the mixing equipment, and some fumes in addition to ammonia fumes.

The cost of a finished product includes the costs in effort and time of using the several ingredients. The techniques for holding more than 3 pounds of ammonia at high efficiency per unit of P_2O_5 in 20% superphosphate become progressively so involved that many operators lapse into means that prove costly long before the comfortable limit of 5.5 to 6.5 pounds has been reached. One study with a batch mixer and a nitrogen solution of mild volatility indicated that the last pound of ammonia in a 6.5 pound ammoniation rate required about 4 times as much time as for each of the first four pounds. Speaking about batch, it is very easy to make those studies. The relationship is probably parallel in the continuous ammoniator also.

Three factors, singly or combined—you will find all three of them applying in some cases; too many cases, I am afraid—complicate the techniques of ammoniation beyond 3 or 4 pounds rate of ammoniation per unit of P_2O_5.

First, the mass has become so warm that much of the remaining ammoniation is performed by ammonia as gas, and gases usually react with dry materials more slowly than do liquids.

Secondly, the easily ammoniated surfaces of the superphosphate particles have already been ammoniated, probably almost to the limit. It then becomes necessary to penerate to the unreacted superphosphate inside of the particle, a slow process, particularly when the ammonia has become a gas. Several studies have shown that as the particle size of superphosphate increases beyond about 30 mesh, the ammonia take-up drops off rapidly.

A third fact tends to limit ammoniation to a point below an expected level. Varying degrees of agglomeration may develop and protect some of the superphosphate from further ammoniation before all of the ammonia has been added. This may be especially true if the first two factors, volatilization of the ammonia and large particle size of superphosphate, have prolonged the time of applying the ammonia.

In other words, we are working for granulation, but we can get it too soon.

The principal techniques that are required to meet these problems may be quite easily stated and even quite easily applied once the principles are understood. Very intimate and uniform contact between the superphosphate particles and the ammoniating medium while the ammonia is still in the liquid state takes advantage of the easy first phase of ammoniation. It is here that time can be saved, as usually the reactions are about four times as fast per pound of ammonia as for the last 15 or 20% of the ammonia.

At substantial rates of ammoniation, gas is going to be generated, and more and more of the ammonia will be reacted as gas as the limit of the process is approached.

Provisions must be made for contacting the ammonia gas uniformly with the superphosphate and for generating this gas no faster than it is going to be reacted. That gets into the skills and observation of the operation as much as the design and maintenance of the equipment. Very few, if any, present commercial devices for ammoniating superphosphate provide for reclaiming much of the ammonia gas if that gas has been generated faster than the surrounding superphosphate can absorb it at atmospheric pressure. Arrangements to do so under pressure have not been widely commercialized.

The simple practice of introducing the ammoniating medium at progressively slower rates as saturation is approached, has been very effective. The practice has the advantage of being applicable to any ammoniating medium from the least to the most volatile, with minimum changes to equipment. The mechanical means for achieving this descending rate of application and of limiting the rate of gas formulation differ between the rotary batch and the continuous systems.

In either the continuous or the batch rotary mixer, the demand for ammonia is far from uniform per inch of length of the mixer throughout the length of the mixers. In the rotary mixer, even if the chemical action were uniform for all of the superphosphate at a given time, the volume of the material per inch of the mixer length in one section may be many times that of another section. In the continuous TVA type of ammoniator throughout its length the volume of the mass is quite uniform. But, the rate of reaction with ammonia and the portion of that ammonia that will be gas must be quite different between the inlet and the outlet ends of the TVA continuous ammoniator.

The ammonia distributor pipe must be considered as a manifold design to accommodate these requirements. The holes should be so spaced, or sized progressively in some cases, that they function as metering orifices. If there are good reasons for having the holes of a given size and spacing to deliver a rather closely defined amount of ammonia to the various regions on the day the system is put into effective operation, there are compelling reasons for seeing that the arrangements are not allowed to degenerate through wear, corrosion, or resort to easy, careless attention to detail by the personnel. I am very happy to see the report on Hastalloy-C. When a pipe is once made that way, it continues. I believe somebody mentioned he had gotten something like 40,000 tons through one pipe, and it was still performing very well.

Regardless of costs, or conveniences, all efforts should be directed to achieve these ends. Ammoniating techniques not only directly affect costs of nitrogen, phosphates, and acids, but they exercise heavy influence on graulation and the condition of pulverized, ammoniated fertilizer.

Since the rate of reaction decreases rapidly beyond the halfway point in high rates of ammoniation, there should be a corresponding decrease in the throughput of ammonia per hole in the distributor pipe in a batch mixer. Also, in the continuous mixer there should be a reduction in the number of holes or in their size toward the outlet end or some other means of coping with the changing demands of the process. In both systems a judicious handling of the gas portion of the ammonia can serve to even out the irregular ammoniation of superphosphate that seems to be inherent in commercial ammoniation with liquids as it is performed today.

For efficient use in application to the fertilizer mass, acids should be distributed uniformly. There is room for serious study on the use of acids for these are used to offset poor original equipment or degeneration of operating skills or equipment. These original failures or declines of techniques are increasing the costs of making fertilizer wherever they occur and they create needless hazards in many instances.

Poor ammoniation techniques can quickly result in excess costs of nitrogen, superphosphates, and acid, in poor condition of pulverized or granulated fertilizer, and some bad fumes in addition to ammonia fumes, truly a long line of indictments.

Comments by Chairman Sauchelli: Thank you, Elmer. That is a fine condensed summary of things.

We have time for one or two questions. Who will be the first to fire at Elmer?

If I didn't know that a lot of questions are fired at these fellows in the corridors and in the rooms, I would be disappointed, but I know that one of the objectives, one of the fine things about our round table, is that it does enable many of these fellows to have small group sessions so they can ask questions. One man told me that in three days here he sees more people than he could see in traveling around three months, and he has had a chance to ask some questions. So even though we don't get too much discussion because of the large crowd here, I feel that as we select two or three speakers to discuss different phases of the subjects we are enforcing discussion, because the people who do discuss are selected right from your own group.

Question No. 14—A Discussion of The Advantages and Disadvantages of Screening Granulated Mixed Fertilizer Between the Dryer and Cooler Versus Screening After the Cooler.

F. A. Retzke

WE have each screening system in operation at different plants in our company. However, I can give only a qualitative comparison because of other differences in formulation and operation among the different plants.

In the hot screening system, that is screening between the dryer and the cooler, (1) the over-size is crushed in a chain mill and returned to the dryer; (2) the on-size goes to the cooler; and (3) the screen fines and cyclone fines are returned at a controlled rate to the ammoniator-granulator. In the cold screening system, screening after the cooler, (1) The over-size is crushed and rescreened without redrying; (2) the on-size goes to pile storage; and (3) the screen fines and cyclone fines are returned, at the rate they are made, to the ammoniator. In the hot system, we formulate with 66° Be sulfuric acid while in the cold system we use 60° Be sulfuric acid and have a separate granulating drum.

With hot screening the temperature of the recycle fines is about 80° higher than with cold screening. This hot recycle adds heat to the goods in the ammoniator, and increases the liquid, plastic phase. This aids granulation in certain formulas whereas adding water might not. Or, less water may have to be added for granulation than with cold recycle. Thus the subsequent drying load is reduced.

For those formulas which normally have a high liquid, plastic phase and high reaction temperature, the additional heat from hot recycle contributes to the evaporation of moisture from the goods in the ammoniator. This tends to dry up the bed and also reduces the drying load.

In some formulas less sulfuric acid may be needed to promote granulation than with cold recycle. This reduces raw material costs.

The crushed over-size, returned for redrying, is also at a higher temperature than from cold screening, which again decreases the drying load.

Screening after the dryer obviously reduces the cooling load, for only the finished product is cooled. In our case, we were able to use an existing cooler, capable of handling up to 25 tons per hour, while the dryer and ammoniator were handling up to 40 tons per hour in order to take advantage in some cases of cheaper raw materials costs by using high recycle rates.

With only the on-size product in the cooler, dust emission from the cooler stack should be less than that from a system which cools all the material from the dryer. I have not particularly noticed the point of attrition in the cooler creating fines in our product, although I do not have any quantitative data on that.

Naturally there are some disadvantages to hot screening. For formulas which have a low water content, a high liquid, plastic phase and a high reaction temperature ,it may be necessary to reformulate to a cooler, less plastic formula. So far we have not experienced this. It might occur in high nitrogen, high P_2O_5 formulas containing nitrate solution and phosphoric acid.

Prior to the start-up of our hot screening system, I was concerned about blinding the screens, particularly the fine screen cloth. However, under normal operating temperatures, we have had no trouble with the Ton-Cap equivalent of 20-mesh with stainless steel wire. It will blind if the temperature of the material, containing nitrates, is above the normal operating temperature.

If the temperature of material containing nitrate is above normal, the hot over-sized does not shatter as easily which in turn increases the over-size load in the system. Such material will also build-up on the interior of the chain mill. With normal material temperatures this is not a problem.

Screen maintenance may be some higher. For example, an ordinary plywood screen cover does not last very long in the hot, humid atmosphere which you get with hot screening.

If the hot recycle is handled on a belt or in an elevator, the life of such equipment may be shortened. Our experience has not been long enough to indicate this.

I think this question is similar to the question of co-current versus counter-current drying. As we said in the Army, it depends upon the situation and the terrain.

L. M. Leach

WE went into the granulation of mixed fertilizer in Indianapolis in the Spring of 1955. There were not many plants granulating at that time and therefore, there was not too much experience on the overall granulation operation.

This is a handicap, but one that maybe you can't see too well. We chose to screen between the drying and cooling operation. It appeared to us that we could do a better job for several reasons:

1. The oversize would still be moist inside therefore would crack real easy to proper size, and the hard dry outer layer would help keep the mill from plugging.
2. After cracking while oversize was still hot, we could run it back to the dryer and save fuel because we would not need to build up temperature to take out the remaining moisture.
3. The fines could be immediately put back into the ammoniator and because they are still hot they would not cool the ammoniator bed. We could get by with less reaction heat therefore use less acid.
4. We could have much more efficient cooling because we would have only product going through cooler, the cooler load would be reduced by the amount of the recycle which often amounts to 100% of production rate.
5. Then there was a fifth reason and that was the fact we already had a cooler and to work it into the system, we would have to make some expensive alterations. So we decided the best way to go was to dry, screen, then cool.

The actual operation has not worked out like we planned. First the oversize unless it was quite a bit to large, was not so wet inside and after it was cracked or crushed, dried very fast so we soon put a bypass after the crusher and ran the material back to the screens.

Another reason too, for the bypass, was to take the load off the dryer. This recycle load seemed to build up unusually fast.

One reason was because if the recycle was not cracked the first time through, it would be one half hour before it went through again; the half hour being the time it takes to go through our dryer.

I see no reason that the fines being hot would help in the granulation process, but that, too, has not been an advantage, since the acid rates are the same at all plants.

There are also other disadvantages to screening hot material. It is no fun trying to clean the fine, bottom screen with hot pills going up your sleeve or down your neck so unless your foreman is constantly watching the screens will blind and fines go to product.

Unless you use stainless steel wire, screens do not last very long. Even with stainless the hot heavy laden ammonium nitrate fertilizer sticks and builds up fast.

And it gives you chills seeing men with scrapers, rubber hammers, or what have you, cleaning high priced stainless steel screen cloth.

Most of the screen cloth doesn't wear out, it just gets cleaned to pieces.

Then too, it is always fun to clean a screen after a batch of fertilizer that has too much acid or gotten too hot in the dryer, or for some other reason has become really gummy, has been delivered to screen. This doesn't happen very often, but when it does you have yourself a mess.

Well what I am saying is I would rather screen after cooling. In the three processes, we put in following Indianapolis, we screen after cooling.

One thing is very true, I think, and that is the cooler is much more efficient when you screen before cooling.

However, you still must have proper equipment. Even though we set up to screen then cool at Indianapolis, we found our cooler would not do the job and we had to change.

Since then, cooling has not been a problem. So, I would rather size the cooler to do the job then screen after cooling.

DISCUSSION

Monitor, V. Sauchelli.

Mr. G. L. Bridger: Like many of the questions discussed today, the answer to this one depends upon the grade of fertilizer you want to make. Each system has certain advantages for different grades.

Perhaps most plants use the system of screening the total fertilizer after it has gone through both the dryer and the cooler. The fertilizer is screened into three fractions. The over-sized is crushed and rescreened; the on-size goes on to storage; the fines go back to recycle.

This system has certain advantages. First of all, if there is any attrition in the cooler, then the fines caused by this attrition are removed by the screens and do not get into the product. Secondly, the recycle is a cool recycle. This is an advantage if you are making high nitrogen grades with high solution uses. You want a cool recycle in this case.

On the other hand, the system in which screening is done between drying and cooling has some advantages. In this case you get a hot recycle. This is advantageous if you are making low nitrogen grades — 1-4-4, for example. You want hot recycle. A second advantage is that you have to cool a much smaller amount of fertilizer. You cool only the on-size material. But this system has the disadvantage of getting attrition in the cooler which is not then removed but goes on into the product unless you want to screen a second time, and the more serious disadvantage abouthigh nitrogen grades when they are hot tend to be sticky and pastic, and are very difficult to screen. So your screening problem, keeping them clean, keeping them from binding, is very serious. You might have to keep a man operating all the time.

All in all, if you have to make both grades, as most of you do, my opinion is that you would be better off to screen after cooling.

Question No. 15—Economics Involved in the Selection of High Capacity Versus Low Capacity Equipment.

Glen Wesenberg & James Madigan

EITHER oversizing or undersizing equipment is costly. Many factors should be considered in selecting the size and/or capacity of equipment to adequately meet production requirements. These factors are especially important in the selection of equipment for producing acceptable granular high analysis grades of fertilizer. In the following summary we have outlined the selection of equipment based on two extreme approaches and modifying the size selection in consideration of existing and desired factors. Although there may be, in any specific case, other factors that will influence the size selection required we hope the following summary will be of assistance as a guide in the selection of processing equipment. The two approaches are equipment selection based on peak demand period requirements or average demand requirements.

A. Selection of Equipment Based on Peak Demand Periods

It is suggested that the month of highest shipping requirements be used as the peak demand period, and that the production rate required based on the peak demand period be determined from a review of the highest requirement month of each of the past five years. This will not only give basic figures but will also show the trend of requirements for the future. Graphical analysis of existing data present can be a helpful procedure in making this study. Selection of equipment based on capacity required during peak demand periods will require high capacity equipment.

B. Selection of Equipment Based on Average Demand

Here, we will define average demand as the average ton per hour requirement based on a normal operating time of 7½ hours per working day and determined from the total tonnage requirement for the entire year. In determining this rate, consideration must be given to vacation time and estimated down-time for repairs and modifications. Here again, past records and available area reports will be a good guide in determining the average demand or requirements. Selection of equipment based on the capacity required to meet the average demand rate will require lower capacity equipment than the selection based on peak demand requirements.

We have given two extremes and normally a selection of equipment will be based on the summary of both of these equipment requirements. The following factors will vary the selected equipment capacity rate accordingly:

(1) *Product Storage Space.*

If available storage space is not adequate to meet the peak demand requirement ment while producing at the average demand rate an increase in the capacity selection of the equipment must be made. Likewise if the peak demand selection basis is used as a reference starting rate the capacity size of the equipment may be reduced in consideration of the available storage space that can be used to supplement the demand during the peak period. Increasing the storage space may prove more beneficial, especially where an increase in number of grades is required rather than maintaining the requirement for high capacity equipment.

(2) *Available & Required Equipment Space.*

If selection of equipment is made on the peak demand requirement and available existing space within the plant is not adequate for the size and amount of equipment required; consideration can again be given to reducing the size and correspondingly the capacity of the equipment and utilizing savings for expanding storage capacity to offset the reduction in capacity of the equipment. Following this procedure a considerable savings can at times be realized by locating the equipment in existing space, as above aisles, where the space can not be used for product or raw material storage.

(3) *Initial Equipment Investment.*

Obviously a higher equipment investment is made if the equipment is selected on the basis of the peak demand requirement rather than if the equipment selection is based on the average demand requirement. If the equipment is based on the peak demand requirement the equipment will remain idle during extended periods throughout the year. As we all know, idle equipment in a fertilizer plant normally has a decrease in life almost as rapidly as if the equipment is in continuous use. If the equipment selected is based on the average demand capacity the equipment would be used continuously throughout the year. During the peak demand period the equipment can be operated on a two or three shift basis and thereby meet requirements during the peak demand period.

(4) *Consideration of Cost of Modification or Obsolescence of Equipment when New and Improved Equipment or Process Procedures Come Up.*

Certainly consideration should be given to process changes and equipment improvement that are arising due to the rapidly changing grade requirements, product quality requirements, and for more extensive process developments that are continually changing the equipment requirements. Not only should this be kept in mind for equipment layout but consideration of the large capacity and long life equipment cost may not be fully warranted.

(5) *Requirement for Overtime and Shift Labor During Peak Demand Periods.*

If peak demand capacity of equipment is selected less overtime and shift labor is required. If the plant is in an area where labor rates are high the straight time labor obviously gives a savings. It also presents problems in hiring and laying off personnel and training personnel for operation of equipment.

(6) *Power Requirements and Cost.*

Here again section of larger equipment requires a larger power supply, corresponding larger transformers, starters, etc. Depending on the agreement with the power company the cost of a power may vary considerably to satisfy peak demands for short periods of time only.

(7) *Rates of Inventory Recovery After Shutdown and Production Planning Required to Build Up Inventory.*

Inventory can be built up much more readily with the higher capacity equipment and unpredictable higher capacity demands can be met with the larger equipment, therefore, production schedules can more readily be met with the higher capacity equipment. With the lower capacity equipment longer range planning must be done in order to meet the demands that occur.

(8) *High Rate Production Versus Low Rate Production Over an Extended Period of Time.*

Low rate production over an extended period of time not only permits operation of the equipment by the same personnel maintaining employment at a more even rate, but it also may be advantageous in obtaining and scheduling raw materials.

We hope this presentation will

be of assistance in the most economical selection of equipment that will be best suited to adequately meet requirements.

Question No. 16—Economic and Qualitative Advantages of a Preblender-Ammoniator-Granulator.

James E. Madigan and Glen H. Wesenberg

IN order to accomplish three distinctively important operations essential in obtaining a homogeneous, granular fertilizer product Fertilizer Engineering & Equipment Company, Inc., has designed a special unit to accomplish dry material and fines blending, ammoniating and granulating on a continuous basis. Accomplishing these phases of manufacture with a single unit is not only less expensive, but less space is occupied and installation and maintenance are simplified and less costly than using three independent pieces of equipment.

1. Preblending Dry Materials

Proper mixing is an important factor in obtaining a homogeneous mixture. Most conventional unit mixers blend materials together after they are assembled into a predetermined batch which accomplishes intimate mixing and homogeneity; however, in subsequent transfer of materials via chutes, conveyors or elevators often precludes the desired effects, since these manipulations tend to segregate the individual materials.

In the Preblender-Ammoniator-Granulator dry materials continuously fed into the preblender section are tumbled and mixed, and spill over the edge of the preblender discharge retention ring, onto the top of the material bed in the ammoniator. This method assures most optimum mixing conditions right up to the time that dry materials are brought in contact with the liquids added in the ammoniating section of the drum. A quick emptying adjustable discharge gate permits speedy emptying of the drum at the end of each particular grade run.

2. Minimizing Formation of Ammonium Chloride Fumes

It is a well known fact that once formed, ammonium chloride fumes are difficult to remove. Needless to say, these fumes are undesirable. Probably the largest amount of chloride fumes when a corroded sparger allows less formation sometimes occurs relatively large quantities of acid to impinge onto a stream of recycled fines having a high potash content.* Subsequent reactions between hydrochloric acid and ammonia yield the chloride fumes. By the use of the FEECO Preblender," recycled high potash fines from screens and cyclones are blended with the dry raw materials before entering the ammoniating section to give a homogeneous feed to the ammoniating section. Decreasing actual formation, rather than removal of ammonium chloride fumes, is an important factor in the use of the preblender.

3. Cost Saving With Unit Piece of Equipment for Mixing, Ammoniating, and Granulating.

A considerable cost savings can be made in using a unit piece of equipment to accomplish mixing, ammoniating and granulating over the expenditure required to accomplish these operations with separate pieces of equipment. Since these operations are accomplished by using a single drum, only one starter, motor, a single set of drives, bearings, wheels, etc., are used which not only gives a savings in initial equipment cost but a savings is also realized in less installation and subsequent maintenance costs. Likewise, less conveying equipment connecting chutes, transitions, etc., are required.

4. Space Savings.

Much less space is occupied by the combined Preblender-Ammoniator-Granulator than that required for unit pieces of equipment for each of these operations. In the conversion to granulation on a continuous basis of existing mixing units the Preblender-Ammoniator-Granulator can be located in the place occupied by the conventional dry batch mixer with only a small amount of additional space being required.

Here again, less elevating and conveying equipment can be used giving a less complex system and corresponding space savings.

5. Flexible Design to Handle Desired Production Rates.

With a knowledge of the desired production rate the capacity of the drum is designed to obtain maximum efficiency in each phase of the operation. Generally the capacity in each section and corresponding retention time are the important factors in accomplishing these operations efficiently.

Two FEECO Preblender-Ammoniator-Granulators are already in operation, and results to date indicate that the pre-mixing chamber is an important asset and valuable addition in the processing of granular fertilizers.

DISCUSSION

E. C. Perrine

The industry is rapidly finding that it has pretty much reached the economical limits in the control of safety and of granulation with existing equipment when they reach 1-1-1 ratios up in the 12-12-12 grades. Speaking of 3-2-2 and 2-1-1 fertilizer grades, making these grades is rapidly advancing the fertilizer industry into chemical processing and away from the chemical methods of manufacturing fertilizers.

The economics, equipment design, safety, and even the training of personnel for making some fertilizer grades includes much that is common to the chemical industry. These points are strongly in evidence where the grades are granulated and the plant is using ordinary ingredients with fertilizer equipment rather than using the more exotic products that are on the market. I mean by that, some of these fertilizer companies, when they get into these grades, are actually making a chemical that is being used in the less well equipped plants but have been made in the final stage in a more complete chemical plant.

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* "Particle Size & Composition studies of Granular Fertilizers" by R. W. Magness and J. O. Hardesty U.S.D.A. April 1954 *Agricultural Chemicals.*

Question No. 17—The Economic and Operational Aspects of Recycle in Granular Fertilizer Manufacture.

S. D. Daniels

THERE is nothing mysterious about recycle or its use in the process of manufacturing granular fertilizers. There are only two reasons for recycling finished product in a fertilizer manufacturing operation. First, it is necessary to recycle fines produced in the sizing operation. Secondly, material is recycled to control the graulation operation.

In order to understand the economic and operational effects of recycle on granular fertilizer manufacture, it is only necessary to understand the process of granulation. Granulation is simply the process of mixing dry fertilizer materials with a liquid in such a way that agglomerates of fertilizer are formed in the particle size range dictated by the consumer.

Control of granulation involves control of the amount of liquid in the granulating medium This liquid is simply a high concentrated solution of soluble fertilizer salts in water. The amount of liquid then, depends upon the amount of chemical heat produced by the formulation.

If the fertilizer formulation contains too much water, the result is over-granulation; if the temperature is too high, the solubility of the fertilizer salts is increased so that too large a volume of liquid is present and over-granulation results. Conversely, too little moisture or too little heat results in too little liquid—hence, too much fine material results.

This concept of granulation is well understood. Recycle added to a fertilizer operation affects the amount of moisture and the temperature in the ammoniator. Understanding this, the use of and the implications of recycle become clear.

When recycle is added to a granulating system, it effectively reduces the moisture content and temperature of the system. It is true that there are many factors which affect the amount of recycle used in a particular granular fertilizer formulation. However, all of these factors come back to the simple fact that the recycle affects moisture and heat in the ammoniator. For instance, a manufacturer may screen his product between the dryer and cooler so that the recycled fine material is hot. The manufacturer finds that his material is over-granulating—his only solution is to reformulate to produce less chemical heat to allow for the heat contributed by the recycled material.

The problem of reformulation brings us to the question of recycle and raw material costs. It is quite generally true that for a particular fertilizer grade as the price for raw materials decreases, the recycle requirements increase because the cheaper formulation does contain more water and/or heat producing raw materials. For instance, in making 12-12-12 in which all of the nitrogen is derived from ammoniating solution, more recycle is required both for the extra water contributed by solution and acid and the greater amount of heat produced from the acid required to react with the free ammonia. In order to correct this and lower recycle requirements, one must replace solution with dry, non-heat producing ammonium sulfate. The way in which variation in recycle changes raw material cost will depend upon location so that one cannot draw general conclusions about this matter.

As in the consideration of operational aspects, the economic implications of recycle come down to the simple consideration of heat and moisture. If to produce a fertilizer at a lower raw material cost it becomes necessary to use those materials which contribute more water or produce more chemical heat the recycle requirements will increase.

It is the responsibility of the fertilizer manufacturer to carefully consider the increased cost of production at a higher recycle rate to determine whether the saving on raw material cost will be advantageous to him.

In summary, the factors which influence recycle rate are those factors which influence the amount of heat and moisture in the ammoniator-granulation process. The effect of recycle rate on raw material cost depends upon the heat and moisture contributions of the raw materials which are used in the manufacturing process.

It is the responsibility of the supervisory personnel in the fertilizer industry who should and do understand the workings of recycle and granulation to teach their operating personnel the meaning of recycle. In this way, the operator will recognize and understand the requirements for granulation control and ultimate product quality will be improved.

Friday, November 7

Economics of Formulation

Comments by V. Sauchelli: We have an interesting program here today. Our theme this morning is the Economics of Formulation. I am sure everyone in the room is very much interested in that theme.

In line with our program this year we have a keynoter to set the stage for the morning's proceedings. We are fortunate indeed to have as a keynoter a man who is thoroughly competent and is thoroughly familiar with all phases of our fertilizer manufacture. The speaker is a graduate of Syracuse University. Early he got his training right after graduation with the Solvay Process. Then he went to the Tennessee Valley Authority at Wilson Dam, where he was engaged first as shift superintendent, and then he became a project leader. He had a very interesting career at TVA. He invented processes. He is credited with two patents pertaining to the TVA continuous ammoniator. He also has two patents on the nitric phosphate process. At TVA he participated in the electric furnace and wet process phosphoric acid work, nitric acid and ammonium nitrate, triple super, calcium metaphosphate, conventional and granulated fertilizers, and what-not. He has been active in every phase of it.

He left the Tennessee Valley Authority, for the benefit of the industry. Let me emphasize this. The TVA may be criticized for certain things. It is not our business here to discuss that. But one thing I think we are all agreed upon is that TVA has been a great constructive force in the fertilizer industry and research, and primarily, in my judgment, in the training of men. I mean that many a good man that they would like to keep there has left the TVA after his training, and entered industry to help our fertilizer industry.

Let me mention a few of the men. I don't have a complete list. But there are Larry Heim, L. D. Yates, George Frear, Russ Jones, Phil Stone, Frank Acorn, G. L. Bridger, Herb Kerr, Bill Williams, Dave Delavan, Robert Russell, Dan Walstock. There are others I have left out without meaning to.

There, gentlemen, is one of the factors which has helped, I believe, in revolutionizing and evolutionizing our business from a scavenger business to a real engineering process industry. The influence of the men trained at the TVA is definite and makes for constructive work.

So I think we ought to recognize and I do recognize the work of the TVA in training men who are very influential and very helpful to our industry as one of its primary jobs. They should be applauded for it.

Our speaker is one of that famous group of alumni of TVA. Without further ado, it gives me great pleasure, and I think it is an honor to us, to have as our keynoter today Frank T. Nielsson, known affectionately to his friends as "Slugger" Nielsson. (Applause).

Frank T. Nielsson

LADIES and Gentlemen and Fellow Alumni:

At this time let me say the boss has gone home, the salesmen have left, and now we have left the people who do the work; now we have the people who can get some sleep if the plant is operating with a good formula.

Our theme this morning is the Economics of Formulation.

The dictionary has many definitions for economy and economics. The ones that I believe apply to us are:

(a) To be sparing in expenditures

(b) To use to the best advantage

The dictionary states also that a formula is a prescription or recipe. Therefore we can say that formulation is a term that deals with the choice of the raw materials to be used in making up a given fertilizer grade.

So far we have been discussing the ways and means whereby best results can be obtained from our personnel, our equipment, and what are the advantages of various flowsheets or means of making a product.

Now we take up the question of how can the fertilizer recipe contribute to cost savings and good operation.

Formulation Starts Out With:

A. Sales objectives; or how much icing is needed to satisfy the customer. Is this a conventional or "powdered fertilizer"? Is it granular or semi-granular? By semi-granular I mean any coarse product not sized. If granular, is it to be closely sized or will it have a wide range of particle sizes? Does the agronomist believe the product has the necessary ingredients for good plant growth.

B. Equipment; or on what model stove are we doing our cooking.

Once the physical dimensions of the product are set, formulation is tailored to equipment. Is it a batch or continuous mixer. If continuous, is it a pugmill or TVA type ammoniator.

Each combination of product specifications and plant flow sheet sets a basic pattern as to what formulae are needed. For example conventional 5-10-10 generally has a lower raw material cost than granular or semi-granular 5-10-10. Granular 10-10-10 generally has a lower raw material cost than does the semi-granular or conventional product. A 10-10-10 formula for a continuous granular plant having only a cooler requires large quantities of free ammonia and sulfuric acid, and will be more expensive than one where a drier permits the use of large quantities of solution having a low free ammonia content.

When the agronomist has spelled out the needs of the customer in terms of major, secondary and minor plant foods and the sales department has set up specifications for physical appearance and condition, the formulator is ready to juggle the large number of available raw materials in a recipe for a given fertilizer grade to suit a particular plant in a definite area.

Allow me to list some of the thoughts that should be going through the mind of the formulator as he makes up a new formula in order that the resultant product will yield the desired degree of customer satisfaction regarding quality along with a fair return on investment to the manufacturer. Although the remarks are slanted primarily toward granulation formulae, some will apply to conventional formulae.

1. What is the net effect on the formula cost of a new raw material? For example, phosphoric acid is more expensive than is triple super. However, by using phosphoric acid, it may be possible to eliminate sulfuric acid, use more, low cost ordinary super, and replace solution with less expensive anhydrous ammonia. The net effect may be a sizeable saving in formula cost if phosphoric acid is used.

2. Can I justify the equipment needed to handle new materials even though they reduce formula cost? For example, it may cost about $4,000 to install new piping and metering equipment to handle phosphoric acid. If 6-24-24 is the only grade in which phosphoric acid will be used, is the tonnage of 6-24-24 sufficient to justify the new installation.

3. What effect will the formula have on the process, technically and economically? For example, using 12 units of solution instead of 8 in a 12-12-12 grade should reduce the formula cost. However, the higher solution rate probably will require more recycle. The higher recycle may require a decrease in tons per hour output. Will the increased labor and overhead cost justify the savings in raw materials cost.

4. Have raw material costs changed so a new appraisal of their value is needed? For example, when sulfate of ammonia was delivering for about $2.15 per unit and solution plus equivalent acid was about $1.70 per unit, the urge to use more and more solution had economic justification. Now that sulfate has dropped to about $1.70 per unit, and the equivalent solution-acid price is the same, a reappraisal of the use of sulfate is needed.

5. What effect will the new formula have on the physical condition of the product? For example, if using 12 units of solution instead of 8 in a 12-12-12 shows an overall saving, will the product be as satisfactory as it was before. Or will the cost of returned goods because of complaints offset the savings in formula cost? Another example is the use of combination urea-ammonium nitrate solutions. Their lower freezing points makes possible the use of low free ammonia solutions during cold weather. However, the same combination of urea and ammonium nitrate that yields a low freezing point results in greater solubility than if one salt alone were present. Therefore the products made with combination solutions become softer at the same moisture pick-up than do products made with either solution alone. As a result, the new product may require further drying to ensure satisfactory condition.

When I was first getting my feet wet in large scale formulation I was very proud because I convinced management that in a conventional 5-10-10, 5 units of a C type solution would materially reduce costs as compared to using 4 units of an A type solution and 1 unit of sulfate of ammonia. The plant superintendent reported the formula was fine at basing time. However, when bag storage tests began to show severe bag set with the new formula, the possible savings went out the window, because the material was unsaleable. I did not have any data then as to how much ammonium nitrate could be tolerated in a grade at a certain moisture content.

What I found out the hard way then, has been repeated by many formulators. It is difficult to convince some operators that a formula that yields a satisfactory product in Amarillo may be all wrong for Biloxi, Mississippi, because of the difference in humidity at the two locations.

6. What is the effect of raw materials on chemical analyses? For example, by using granular potash instead of standard muriate, it may be possible to use a low heat formula using solution and no sulfuric acid. However, the granular potash may not become incorporated with the other raw materials and the resultant segregation in the pile may result in very erratic analyses.

7. What type of product will satisfy the customer? For example, if the customer is satisfied with a wide variation in particle size, a low heat, low recycle formula can be used. If the customer requires a closely sized product, recycle will be high, and therefore the formula can be one that works best with high recycle.

8. How will the formula affect working or operating conditions? For example, a low cost material may be so dusty that it affects employee morale, causes hazardous working conditions, and contaminates other materials. Then again, the formula may yield excessive oversize that will not dry properly with resultant stoppage of mills and blinding of screens.

9. How will the formula affect air pollution? For example, the cheapest formula may be one where excessive solution is used, knowing that a high free ammonia loss will result. If plant ventilation is inadequate, employees suffer. If good ventilation is available, the neighbors may complain. Or, a spent acid may be fine in all respects except for the smell evolved during its use.

10. Are there any gimmicks that may affect the cost of a particular raw material? For example, two materials may have the same FOB cost and freight rate, but one may be trucked into the plant by dump truck with no unloading cost whereas the other may require the use of plant personnel for unloading.

11. How much drying does the formula require? The degree of drying affects the heat input into the drier and the throughput. Goods that will move directly into the field do not need the same degree of drying as that required by the same goods if they are to be stored in a bag warehouse for months.

12. What are the storage problems? For example, is it more economical to tie up a 500 ton bin with 100 tons of 3-12-12, or is it better to dilute 4-16-16 with dolomite at time of shipment for such a small tonnage.

You may have noticed I stopped short of having the formulator have a thirteenth point messing up his calculations. That is because finally there is a point at which all that the formulator can do is to say that the formula is a good starting point and further changes will have to be made after a plant trial.

I hope that this talk may have brought some new thoughts into the economics of formulation.

Question No. 1—What Is the Factor that Establishes Whether a Formula Is Low or High Analysis?

W. L. Hill

THE importance to the fertilizer industry of the designations high-and low-analysis is attested by their inclusion among the items for attention in the Round Table this year. Immediate interest lies in practical criteria for their differentiation. For obvious reasons primary consideration must be given to NPK fertilizers.

Criteria

One school holds to the view that the top of the low-analysis category is the maximal grade that is producible from ordinary superphosphate without fortification with a higher-grade phosphorus carrier. On this basis a 10-10-10 fertilizer, about 30% of ($N + P_2O_5 + K_2O$) would be the maximal low-analysis grade. Another school would use the national average nutrient content of mixed fertilizers consumed in the most recent year as the point of division. In 1956-57 this figure was 29.54%, so that, as of today, both criteria lead essentially to the same place—30%.

General acceptance of any standard of grade highness can come only if the rule satisfies the sensed need of the industry. If then the foregoing figure be a reasonable one that will serve the trade fairly, it must meet the needs in *all* market areas.

The Market Situation

On a regional basis the average grade falls from New England to the Southeast, then gradually rises through the South Central and Mountain regions, and becomes highest in the North Central States. The path of change is thus a spiral beginning in the Northeast and ending in the North Central States.

The situation is, however, much more realistically depicted by a plot of the State averages (Fig. 1) pg. 61. The curve, drawn near the upper boundary of the field of points, is intended merely to indicate the general pattern presented by the plotted figures. State averages, rounded to the nearest whole number, range from 21 (Florida) to 44% (North Dakota) with a mid-range figure of 32.5% in comparison with the national average of 29.5%. This is a rather broad range. A relatively high-analysis fertilizer in one State turns out to be a relatively low-analysis product in some other State. At the same time, the grade may meet soil needs under the dominant management practice in the first more adequately than would the high-analysis goods marketed in the second. Hence, the manufacturer serving the first area properly resents the mild stigma associated with dubbing his best product a low-analysis fertilizer. Obviously then, regional differences in market demands, rather than cussedness of vendors, is the chief obstacle to uniform usage of current terminology.

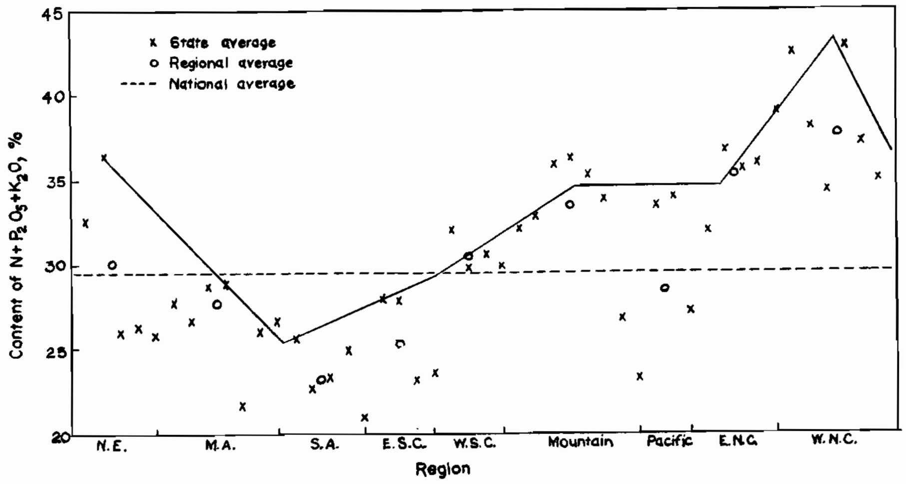

Figure 1. Average Nutrient Content of Mixed Fertilizer Consumed in the United States in 1956-1957. Plotted figures are from Scholl et al., Com. Fert. 97(1):27-38, 43-45 (1958).

Are Terms Really Needed?

A reviewer of this piece demanded, What good comes from a high-low classification of fertilizer grades? Fertilizers are represented as being accurately formulated to provide a balanced nutrient supply for crops under established management practice. The term *high-analysis* can provide no assurance of agronomic worth. Against this view, effectual defense is difficult to find.

Alternatives to Complete Discard

A requisite for retention of the terminology is an acceptably fair basis of classification. It must bring into joint perspective the sensibilities of manufacturers and vendors, the variable farm requirements from region to region and the technologist's ability to produce concentrated products. This end can be achieved by either of two general approaches. The fore-mentioned reviewer, commenting further, suggested that the high-low classification might be based on State or regional averages. Sectionalization of the criterion would, of course, mean a sliding scale for the several market areas. The other approach is the introduction of a third category—low,- medium, and high-analysis. Two arbitrarily chosen points of subdivision might be accepted more generally than one very logical selection based on formidable arguments. What should be the arbitrary choices? The distribution of the 69 principal grades (1956-57) on the scale of nutrient content is shown in Table I. It is suggested that the

Round Table select the points for subdivision, if perchance a triad of classes seems to meet industry's need.

Table 1. Distribution of Sixty-Nine Principal Grades[a] Over Market Range of Nutrient Content

Nutrient Content	Grades	Nutrient Content	Grades
% of $(N + P_2O_5 + K_2O)$	Number	% of $(N + P_2O_5 + K_2O)$	Number
20	11	29	None
21	5	30	6
22	2	31	None
23	None	32	1
24	5	33	1
25	2	34	1
26	2	35	2
27	5	36	4
28	2	>36	20

[a] From Scholl et al., Com. Fert. 97(1): 27-38, 43-45 (1958).

Question No. 2a—What Is the Maximum Ammoniation Rate for Using Anhydrous Ammonia With the Several Phosphatic Materials?

W. W. Harwood

THE phosphatic materials to be included in this discussion are normal or ordinary superphosphate, triple superphosphate made from "wet process" phosphoric acid and phosphoric acid, both "wet process" and electric furnace. These materials represent the large majority of the phosphate-bearing materials being used in mixed fertilizer manufacture and are those that are involved in the ammoniation reactions.

Ammoniation of phosphatic materials in the manufacture of mixed fertilizers is, in reality, a series of chemical reactions between the uncombined ammonia added and the acidic components of the phosphatic materials, originally present or formed during the reaction steps. In this paper, the term "ammoniation rate" is used to denote the pounds of anhydrous ammonia *absorbed* per unit or per 20 pounds of available P_2O_5, even though the term is commonly used in the fertilizer industry to refer to the pounds of ammonia *added* per unit of available P_2O_5. Since the "theoretical maximum" ammonia absorptions do not conform to those rates which can be achieved in actual operations, it was decided to treat this subject in three phases. These are: 1. Chemical or theoretical reactions. 2. Influences of physical factors. 3. Operational factors.

I. Chemical or theoretical reactions

A. *Superphosphates*

The approximate percentage compositions of superphosphates are given in Table 1. The ammoniation reactions are based only on the water soluble phosphates, namely phosphoric acid and mono-calcium phosphate. However, a small amount of additional ammonia may react with the citrate soluble-water insoluble phosphates. The calcium sulfate does enter into the ammoniation reactions by providing the calcium to combine with the phosphate thereby permitting the ammonia to combine with the sulfate. The presence of the calcium sulfate in large quantities in normal superphosphate is the reason that normal superphosphate has a higher ammoniation rate than triple superphosphate has.

Table 1. Percentage Composition of Superphosphates.

	Normal	Triple
Monocalcium phosphate, $Ca(H_2PO_4)_2 \cdot H_2O$	23-30	63-73
Citrate soluble-water insoluble phos., including dicalcium phosphate, iron and aluminum phosphate complexes	5-9	13-18
Calcium sulfate, $CaSO_4$	45-50	3-6
Silica, fluosilicates, organic matter, unreacted rock, etc.	8-12	5-10
Free moisture	3-6	3-6

The accepted principal reactions that take place in the ammoniation of superphosphate (1, 2, 3) are given in the order in which the reactions are believed to occur:

For normal and triple superphosphates

(1) $H_3PO_4 + NH_3 \rightarrow NH_4H_2PO_4$

(2) $Ca(H_2PO_4)_2 \cdot H_2O + NH_3 \rightarrow CaHPO_4 + NH_4H_2PO_4 + H_2O$

For normal superphosphate

(3) $2CaHPO_4$ (from reaction 2) $+ 2NH_3 + CaSO_4 \rightarrow Ca_3(PO_4)_2 + (NH_4)_2SO_4$

(4) $NH_4H_2PO_4$ (from reactions 1 & 2) $+ NH_3 + CaSO_4 \rightarrow CaHPO_4 + (NH_4)_2SO_4$

(5) $2CaHPO_4$ (from reaction 3) $+ 2NH_3 + CaSO_4 \rightarrow Ca_3(PO_4)_2 + (NH_4)_2SO_4$

For triple superphosphate

(3) $2CaHPO_4$ (from reaction 2) $+ 2NH_3 + CaSO_4 \rightarrow Ca_3(Po_4)_2 + (NH_4)_2CO_4$

(4) $NH_4H_2PO_4$ (from reactions 1 & 2) $+ NH_3 \rightarrow (NH_4)_2HPO_4$

(5) $3CaHPO_4$ (from reaction 2) $+ 2NH_3$ >40°C $\rightarrow (NH_4)_2HPO_4 + Ca_3(PO_4)_2$

Based on the average chemical compositions of the representative superphosphates given in Table 1, the calculated stoichiometric or "theoretical maximum" pounds of ammonia absorbed per unit of available P_2O_5 for each reaction are:

	Normal superphosphate		Triple superphosphate	
Reaction No.	Increment	Summation	Increment	Summation
1	.6	.6	0.3	0.3
2	1.9	2.5	2.0	2.3
3	1.9	4.4	0.5	2.8
4	2.5	6.9	2.2	5.0
5	2.5	9.4	1.0	6.0

Reactions 1 and 2 which take place very rapidly are the reactions between the ammonia and the water soluble phosphates, namely phosphoric acid and monocalcium the dicalcium phosphate from reaction 2, ammonia and some calcium sulfate results in a small loss of availability of the P_2O_5, since phosphate. Reaction 3 involving precipitated tricalcium phosphate is only partially available, approximately 80%. The ammonia absorption in this reaction is much larger for normal super than for triple super since the calcium sulfate necessary for the tricalcium phosphate formation is in much greater abundance in normal superphosphates. It was pointed out by White, Hardesty and Ross (2) that no appreciable additional tricalcium phosphate is formed until an ammonia absorption corresponding approximately to reaction 5 is reached, at which point the majority of the phosphate would be in this form. With the ammoniating equipment in use, it is impossible to achieve the maximum ammoniation rates shown in reaction 5, since this maximum degree of ammoniation can only be approached by prolonged treatment with ammonia at temperatures and pressures that are impossible to attain economically in processing equipment. There is a linear decrease in the water solubility of the P_2O_5 of normal superphosphate with increases in ammoniation rates; while under the same conditions, the water solubility of the P_2O_5 of triple superphosphate levels off between 50-60%, when expressed as % of available P_2O_5 in the original material (3, 4).

B. *Phosphoric Acids*

The reactions that take place in the full ammoniation of phosphoric acid are:

(1) $H_3PO_4 + NH_3 \rightarrow NH_4\,H_2PO_4$

(2) $NH_4H_2PO_4 + NH_3 \rightarrow (NH_4)_2HPO_4$

(3) $H_2SO_4 + 2NH_3 \rightarrow (NH_4)_2\,SO_4$

Based on 54% P_2O_5 acid (75% H_3PO_4 for furnace acid and 67% H_3PO_4 and 2.5% H_2SO_4 for wet process acid), the "theoretical maximum" pounds of ammonia absorbed per unit of available P_2O_5 for each reaction are shown in Table I above.

Table I

	Furnace Acid		Wet Process Acid	
Reaction No.	Increment	Summation	Increment	Summation
1	4.8	4.8	4.3	4.3
2	4.8	9.6	4.3	8.6
3	—	—	.3	8.9

The remaining P_2O_5 in wet process acid is present as iron and aluminum phosphates which are available according to AOAC methods and are beneficial in granulation processes.

II. Influences of Physical Factors

The effects that the physical properties and moisture of the superphosphates have upon their ammonia absorption were covered very completely by Kumagai, Rapp and Hardesty (4) when anhydrous ammonia is used as the only source of ammonia. For this work, a bench-scale laboratory rotary ammoniator was used with a period of four minutes allowed for ammoniation and mixing.

1. *Porosity*
   Superior ammonia absorptions were obtained with superphosphates containing soft and porous particles than those materials containing hard and dense particles. Porosity is probably the most important physical property that affects ammoniation.
2. *Particle size*
   When materials of the same porosity were tested, ammonia absorption increased as the particle size of the superphosphate was decreased from 5 to 80 mesh.
3. *Initial moisture content*
   Ammonia absorption increased as the free moisture content was increased from 1% to 7%. Conclusion was that the desired moisture content should be 3-6%.

In addition to the influences of the physical characteristics upon ammoniation, they showed the effects of reaction temperatures and reaction time.

1. *Reaction temperature*
   The reaction temperature for normal superphosphate is not important; however, increases in the reaction temperature for triple superphosphate resulted in increases in ammonia absorption. Optimum temperature appears to be near 212°F.
2. *Reaction time*
   Every chemical reaction requires time; therefore, the minimum reaction time for efficient ammoniation should be not less than 3 minutes.

III. Operational Factors

Even though it is neither practical nor economical to ammoniate phosphatic materials at the "theoretical maximum" ammoniation rates, as previously discussed, the following operational factors (5, 6) must be considered in order to obtain maximum ammoniation rates with minimum nitrogen losses. These factors must be established for a particular plant using specific equipment and then controlled accordingly.

1. Correct formulations in order to have the proper reaction mixtures possessing the following and avoiding any possibility of excessive plasticity:
   a. Properly sized raw materials with maximum porosities.
   b. Adequate moisture content and controls.
2. Proper control of physical conditions through correct selection and operation of ammoniating equipment in order to obtain:
   a. Homogeneity of mixing.
   b. Thorough mixing in a fairly dense bed in order to provide intimate contact between the reactants.
   c. Sufficient reaction time in the ammoniator.
   d. Adequate temperature control.
   e. Proper ventilation.
3. Proper selection and maintenance of the equipment, auxiliary to the ammoniator, such as,
   a. All metering equipment should be kept in good working condition, free of dust and corrosion.
   b. Use of corrosion-resistant distributors for both ammonia and acid, properly located. If acid is used in the formula-

tion, the complete neutralization of the acid with ammonia is desirable in order to prevent the acid from reacting with any ammonium nitrate or potassium chloride present, thus avoiding the formation of nitric or hydrochloric acids. These acids are very corrosive and cause large stack losses.

4. Adequate drying facilities with proper controls. a.) The amount of water-soluble materials in the final product determines the moisture level to which the material must be dried. The maximum allowable moisture usually is about 4% and frequently is less than 2%. Excessive moisture can cause caking and/or reversion of the phosphate to an unavailable form. b.) High drying temperatures can result in high nitrogen losses.
5. Cooling facilities.

   The product should generally be cooled to 100°F-125°F in order to minimize phosphate reversion and ammonia losses.
6. Avoid use of materials in the formulations that may bring about secondary heating in the curing piles, such as calcium carbonate limestone, magnesium suilfate, potassium carbonate, other alkaline materials, and in some cases dolomite. These materials in certain formulations can result in phosphate reversions and ammonia losses.

In conclusion, it can be stated that due to various limitations, the ammoniation rates, expressed as pounds of ammonia per unit of available P_2O_5, for phosphatic materials are commonly regarded in commercial operations to be 5-6 pounds for normal superphosphate, 3-4 pounds for triple superphosphate, 6.5-7.5 pounds for "wet process" phosphoric acid and 7.5-8.5 pounds for "furnace" phosphoric acid. Many plants are able to operate at the upper limits of these ranges or even at slightly higher rates through proper maintenance of the various controls and through close surveillance of their operations. With the improvements that are being made in equipment, technological "know-how" and raw materials, it is conceivable that the ammoniation rates presently employed will be increased appreciably in the future as they have been in the past.

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Question No. 2b—What Are the Physical and Chemical Specifications for Triple Superphosphate to Get a Good Granulation?

W. W. Harwood

IN most granulation plants, the ammoniation and granulation processes are generally closely connected. Therefore, when considering the physical and chemical specifications for triple superphosphate necessary for good granulation, the ammonia absorption properties of this material must be considered also.

For good ammonia absorptions, Hardesty and co-workers (1) reported that superphosphates should consist of fine, soft and porous particles rather than coarse, hard and dense particles. They found that the initial moisture content of the material should not be less than 3% when anhydrous ammonia is used as the source of nitrogen. These properties are not considered to be in conflict with the properties desirable for good granulation.

The proper proportion and control of the liquid phase is one of the most important factors governing the granulation of mixed fertilizers (2, 3). The liquid phase which consists of the solution of the soluble salts present in the mixture is essential for the production of the necessary plasticity or cohesiveness of the mass. If the amount of liquid phase is too small, insufficient plasticity may result in an excessive amount of fines to be recycled. Too much liquid phase may cause excessive agglomeration resulting in large lumps causing mechanical difficulties and loss of production.

The amount of liquid phase present in granulation processes is dependent upon:

1. Composition of the formulation mixture.
2. Heat present, due either to chemical reactions or to other sources, such as steam, hot air, etc.
3. Amount and form of moisture, present in the raw materials or added as water and/or steam.

Mixtures containing large amounts of soluble salts can be granulated at low moisture levels if the operating temperatures are sufficiently high, since elevated temperatures increase the solubility of the salts comprising the liquid phase. In formulations containing small quantities of soluble salts, it may be necessary to use additional moisture to assist granulation. In the case of low nitrogen formulations, the temperatures resulting from the ammoniation reactions are generally too low for good granulation; therefore, it is frequently necessary to attain higher temperatures by the reaction of ammonia with sulfuric or phosphoric acids. Higher temperatures may be obtained through the use of anhydrous ammonia in conjunction with or instead of nitrogen solutions due to the cooling effect of the water content of the solutions.

Granulation resulting from formulation and heat of reaction is preferable to granulation through increased moisture content due to the economical aspects and the durability of the granule. If added moisture is required, more durable granules can be obtained generally with steam than with water.

A recent paper by some TVA investigators (4) reported a study of the effect of raw material particle size on the granulation of mixed fertilizers. Although their work was primarily concerned with the use of potassium chloride of different particle sizes, the use of granular triple superphosphate in different formulations was investigated. The screen analysis of the triple used in this work was: −6 + 10, 67%; − 10 + 16, 23%; − 16 + 28, 7%; − 28 + 48, 2%; − 48, 1%.

From their investigations, the following conclusions were made concerning the use of granular raw materials as a source of part of the solid raw materials required:

1. In formulations that require some aid for proper granulation, such as 4-16-16 and 5-20-20.
   - A. Granulation efficiency was improved when a portion of the solid raw materials was nearly equal in size to the desired product granule size. The particles of granular raw materials serve as cores or nuclei around which the other ingredients form into fertilizer granules.
   - B. The percentage of on-size granules increased.
   - C. The strength of the granules increased.
   - D. The amounts of other aids, such as steam, water and/or acid, required for granulation decreased.
   - E. Granular superphosphates were equally as effective as granular potassium chloride as an aid in granulation.
2. In formulations that granulate readily, such as 12-12-12,
   - A. The presence of granular raw materials was not advantageous; however, neither was their presence seriously detrimental to the control of granulation.
   - B. In some cases, the granules produced from fine raw materials were more nearly homogeneous and more regular in shape than those made with coarse raw materials being present.

In conclusion, this question may be answered by stating that the physical and chemical specifications for triple superphosphate to possess in order to attain a good granulation, are dependent upon (1) the specific composition of the formulation to be made, (2) the ammoniation rate desired, and (3) the processing equipment, facilities and method; including primary and auxiliary to be employed. Generally, the use of coarse or granular triple may offer some advantages in those formulations which are difficult to granulate, such as the 1-4-4 ratios; however, the ammonia absorption properties of the respective form of triple must be fully considered. The use of fine or run-of-pile triple is advantageous in those formulations which granulate readily such as the 1-1-1 ratios.

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H. B. Tatum

We should first define what we mean by good granulation. Good fertilizer granulation may be defined as a mixture of reacted raw materials that has agglomerated at a temperature to yield most granules in the desired particle size range. The analysis, shape and color vary to a slight degree. The granules dry and cool easily. Medium hardness and high water solubility are other properties.

Pile set and bag rot are just nonexistent.

Essentially, there are two types of granulating plants; the fully-integrated and the semi-granular. Each has its merits and each requires a different triple.

The two triples in question are ROP and Coarse. Chemical specifications are the same, but there are variations in the screen size distribution, surface area and rate of ammoniation. Porosity should not vary.

Chemical Specifications for Triple Superphosphates are:

Available P_2O_5	46 to 47.5%
Free acid	2 to 4.5%
Moisture	3. to 5.5%

Physical Specifications for Triple Superphosphate (in general terms)

	ROP	COARSE
Screen size distribution	Fine	Coarse
Surface area	High	Intermediate
Rate of ammoniation-pounds per unit P_2O_5	3.5 to 4 lbs.	2.5 to 3 lbs.
Porosity	High	High

R.O.P. Triple is produced for the manufacture of high analysis mixed fertilizers in the fully-integrated granulating plant. Higher temperatures are reached as a result of free ammonia neutralization by phosphates, thus promoting plasticity and agglomeration.

Coarse Triple, a special product combining granular characteristics with an intermediate ammoniation rate, assists in producing granules of high yield and quality from the semi-granular plant. The relatively few fines in Coarse Triple are necessary for coating the potash and other ingredients.

Having two types of granulating plant with variations of each and having two types of triples, the problems of manufacturing 1-1-1 and 1-4-4 grades were most challenging at first. Now general conclusions are drawn:

1. Fully-integrated granulating plant:

Grade to be made	Type(s) of Triple
1-1-1	R.O.P.
1-4-4	R.O.P. (and small amount of coarse)

2. Semi-Granular plant:

Grade to be made	Type(s) of Triple
1-1-1	Coarse (and small amount of R.O.P.)
1-4-4	Coarse

Water, nitrates, free ammonia, potash, sulphuric acid and other raw materials play their respective roles in granulation. However, it should not be overlooked that the selection of the proper Triple Superphosphate for the type of granulating plant and grade to be produced is fundamental to the assurance of good granulation.

DISCUSSION

Mr. T. E. Martin: I think Mr. Harwood has done an excellent job of covering this subject. This is a question where I think everybody in the room has his own ideas on what are practical maximum ammoniation rates for the various phosphatic materials we use. We are normally using and recommending to our customers these ammoniation rates: For triple, 4 pounds per unit of APA; for super, 6 pounds per unit; and for phosphoric acid of any kind—and of course there is a slight difference between wet process acids and furnace acids—7 pounds per unit.

Some of our customers throw up their hands in horror and say these are away too high. Others use them without any complaint or use these or very similar amounts.

From the Floor: Would you repeat the figures?

Mr. Martin: Triple, 4 pounds. I believe Mr. Harwood said 3 to 4. Super, 6 pounds. Mr. Harwood said 5 to 6, if I remember right. Phosphoric, 7 pounds. He said 6½ to 7½. That is about the same figure.

These are not maximum rates in any theoretical sense, in that these rates can usually be attained without appreciable loss of ammonia provided the ammonia is mixed in suitable mixing equipment. They may be regarded as maximum practical rates, at least at present.

The rate for phosphoric acid can be run up to 7½ pounds per unit with reasonably careful operation, without appreciable ammonia loss.

It seems to me that a couple of years ago Mr. Hignett or someone else from the TVA told us that they were able to get, I believe, over 5 pounds of ammonia into a unit of APA in triple, using a TVA ammoniator at that time.

Of course, the attainment of maximum ammoniation rate is a kinetic problem. By that, of course, I mean that if you expose any phosphatic material to ammonia, there is a definite rate at which the ammonia will react with the phosphate. Ammonia being as volatile as it is, it is quick to disappear into the surrounding air. If the reaction rate is not fast enough, part of the ammonia will be lost.

It is known that much higher rates than the above can be obtained if sufficient time for obtaining equilibrium is allowed. Practically, there is a definite limit on the reaction time or mixer hold-up tonnage. The design and state of maintenance and the operation of the mixing equipment all have very important effects on the reaction kinetics. The physical condition, as Mr. Harwood said—the porosity, the state of fineness, and the moisture content of the solid phosphatic materials—is of great importance. It is well known that higher temperatures increase reaction rates, at least up to a point. Therefore, the amount of ammonia absorbed is increased.

I think Mr. Harwood has covered all of the other things that I might say. I think the point is covered very adequately.

Chairman Sauchelli: Thank you, Tom.

Now we shall ask Barney Tatum to handle the second part of the question, and then we will put the question to the floor for open discussion.

(Mr. H. B. Tatum then presented his prepared paper, marked No. 4-D.)

Chairman Sauchelli: Thank you, Barney.

Now the question is open for discussion from the floor. Who has a question?

Mr. Richard Taylor: My question is, What is the influence of the presence of single super on the ammoniation rate of tripple super used in mixtures? Can we expect a higher ammoniation of the triple by having single super present? Can somebody give some information on that?

Chairman Sauchelli: Bill, do you want to handle that?

Mr. Harwood: I would say yes, in this manner: You do have added calcium sulfate along with the normal super which will contribute to the over-all increase in your ammoniation rate.

Chairman Sauchelli: Do you want to add anything to that, Barney?

Mr. Tatum: I think the question is answered very well, Dr. Sauchelli. Mr. Tayloe has just answered it. He said that he, too, thought that that was the answer to the question.

Chairman Sauchelli: Any other question?

Mr. Frank T. Nielsson: I would like to talk to Mr. Tayloe and tell him the Monsanto people gave a paper on formulation, and in that paper they have a chart which shows for ordinary super 1-8 mix, triple super has other effects. Depending upon what proportions of each material are in the formula, you dray your line for the average ammoniation rate of the mixture. I am sure that will be published.

Chairman Sauchelli: Where was that paper given, Frank?

Mr. Nielsson: The TriStates meeting up in Chicago.

Mr. W. W. Whitlock: I have a comment. The question of ammoniation rate cannot possibly be seriously considered without a consideration of what type of product we want. If we marry ourselves to a 4-6-7 figure, which is no doubt a good figure for running the slide rule, and then disregard the type of product that we are concerned with, then we might as well forget about the ammoniation rate to begin with. In a 5-20-20 or 4-16-16, for instance, what good is your particular ammoniation rate if you are under-ammoniated? In a 1-1-1 ratio, for instance, what good is your ammoniation rate if your product pH is so low that you have to coat the material in order to guarantee any reasonably good condition- What amount of water solubility is desired in the particular product in the particular area?

These things definitely affect the ammoniation rate. We cannot marry ourselves to these numbers. We have to ask what kind of product we want.

Chairman Sauchelli: Any other questions? I know this affects everyone here and everyone is interested in these problems of formulation.

Mr. Jonathan H. Sprague, Jr. (Freeport Sulfur): Are these ammoniation rates for anhydrous ammonia about the same or slightly higher than or slightly lower than the comparable ammoniation rates with solutions?

Chairman Sauchelli: Bill Harwood, you gave the rates.

Mr. Harwood: I would say yes. After all, when you use solution you have so much free ammonia that will react. So it should apply for solutions as well as anhydrous.

Chairman Sauchelli: Any other comment or question? (No response.)

Question No. 3 — What is the Formula Usage, Cost, and Availability of Diammonium Phosphate, Superphosphoric Acid, Phosphoric Acid, Calcium Metaphosphate, and Triple Superphosphate?

Chairman Sauchelli: We shall go to the third question. I am sure everyone will be interested in the next discussion. We are interested in all of them, but here is one which is another these multiple questions.

(Question No. 3 was read.) That is one of those big questions. Fortunately, we have a man thoroughly familiar with problems of this kind to discuss it for us this morning. We are always grateful to this next speaker for all the help he constantly gives the Round Table committee, and particularly myself. So it gives me great pleasure to call on Travis Hignett, of TVA, to handle this multiple question. I know he will do an excellent job.

T. P. Hignett

SINCE TVA is at present the only source or a principal source of three of these materials, I would like to outline the conditions under which these materials are available from TVA to the mixed fertilizer industry.

A primary purpose of TVA's production of fertilizers is the introduction of new products and new processes. To introduce new materials more effectively, TVA has recently established a procedure whereby any fertilizer manufacturer may obtain limited quantities of new materials for use in the production of new or improved mixtures, higher analysis mixtures, or for determining what advantage the new materials may have. This new program is in addition to our distributor demonstration program in which a limited number of manufacturers or distributors use TVA's products or distribute them in an educational program.

Each manufacturer may apply for a maximum of 200 tons of each of the new materials in a fiscal year. The applicant is requested to describe the processes or products in which the new materials will be used and to agree to furnish TVA with a report of his experience on completion of his tests. Applications are approved when it appears that the planned use of the material will contribute to advancement of technology in producing higher analysis, more economical, or otherwise improved mixtures.

The materials available at present under this program are calcium metaphosphate, superphosphoric acid, diammonium phosphate, ammonium phosphate-nitrate (30-10-0), and high-analysis superphosphate (54% P_2O_5).

The prices of these materials are set somewhat lower than the expected commercial price as an incentive for manufacturers to try them out. If the new materials are successful, it is expected that commercial producers will become interested in supplying them.

Following are the current prices of the TVA materials for bulk shipments, f.o.b. Sheffield, Alabama.

Material	Price, $	
	Per unit of available P_2O_5	Per ton
Concentrated superphosphate(54% P_2O_5), run of pile	1.013	
Calcium metaphosphate (64% P_2O_5), flat grades	1.033	
Superphosphoric acid (76% P_2O_5)	1.473	
Diammonium phosphate (21-53-0)		96.16
Ammonium phosphate-nitrate (30-10-0)		58.00

Market Prices

Manufacturers of triple superphosphate, phosphoric acid, and diammonium phosphate were asked to provide information on the price and availability of their products.

Replies were received from nearly all of the companies that were contacted.

Twelve companies identified themselves as suppliers of triple superphosphate to the fertilizer industry. Two of these quoted prices only in the western states and only on granular superphosphate.

Bulk, nongranular triple superphosphate was uniformly priced at \$0.98 per unit plus freight from the vicinity of Tampa, Florida. Even when the origin was other than Florida, the price was adjusted to compete with Florida material in midwestern areas. Delivered prices were quoted for the western states.

Eleven companies identified themselves as suppliers of wet-process phosphoric acid, and seven supplied furnace-grade acid. The price of wet-process acid was usually \$1.36 per unit, f.o.b. point of production. Most producers mentioned that freight was equalized against the nearest competitor's plant. The usual concentration was 52 to 54 per cent P_2O_5.

Furnace-grade acid was quoted at \$1.48 to \$1.56 per unt. Most companies quoted the higher price; some quoted a price range of \$1.48 to \$1.56. These prices are f.o.b. point of production; there are about seventeen production points scattered over the United States.

Diammonium phosphate (21-53-0) was quoted at \$103 per ton (bulk, f.o.b. plant) by one eastern producer. Two producers on the west coast quoted \$125 per ton. A granular diammonium phosphate made from wet-process phosphoric acid (18-46-0) is available in pilot-plant quantities at \$75 per ton, bulk, f.o.b. East Tampa.

Delivered Costs: Typical delivered costs of triple superphosphate are \$1.20 to \$1.40 per unit, usually about \$1.30 in the Midwest. A typical delivered cost for wet-process phosphoric acid may be about \$1.45 per unit.

In California the delivered cost of wet-process phosphoric acid is about \$1.50 per unit; bulk superphosphate is \$1.60 to \$1.70. In some other western states the delivered cost of both materials is about \$0.10 per unit lower.

Although the discussion topic assigned to me does not include ordinary superphosphate, it is necessary to assume some cost for this material in order to discuss the economics of formulation. The cost varies widely, depending on location and whether it is produced or purchased by the mixed fertilizer manufacturer. Perhaps a range of \$0.90 to \$1.20 per unit is typical, although both higher and lower costs are fairly common.

Formula Usage: Formulations using triple superphosphate are generally well known. Usually it is used in combination with ordinary superphosphate in such proportions as are required for the desired grade. In the 1-4-4 ratio, for instance, 3-12-12 can be made without triple superphosphate; 4-16-16 and 5-20-20 can be made with different proportions of ordinary and triple superphosphate.

The higher analysis products usually are cheaper per unit of plant food even though the raw materials cost somewhat more. This is because of savings in processing, storing, bagging, and transporting the products. It is estimated that these costs amount to about \$15 per ton of product regardless of the grade of the product. If we divide \$15 per ton by the number of units, we find that these processing, handling, and shipping costs amount to \$0.56 per unit of 3-12-12 but only \$0.33 per unit of 5-20-20. This difference usually more than offsets the higher cost of the raw materials for the higher analysis grades.

Sometimes we become so intent on increasing the analysis of fertilizers that we may lose sight of the economics. There are cases in which increasing the analysis may not result in lower cost of fertilizer delivered to the farmer. This may be true when ordinary superphosphate is available at unusually low cost and when higher analysis materials are relatively expensive.

Phosphoric acid may be used to replace part or all of the triple superphosphate in formulations for high-analysis fertilizers.

The advantages and disadvantages of formulation with phosphoric acid rather than triple superphosphate are:

Advantages

1. The formulation cost is usually lower.
2. Less fuming and better nitrogen recovery due to elimination or decreased use of sulfuric acid.
3. Higher analysis grades are possible.
4. Improved granulation with some grades.

Disadvantages

1. Equipment cost for handling and metering acid.
2. High water content restricts use to those plants that have dryers.
3. High water content may cause difficulty in controlling granulation of high-nitrogen grades.

The fact that formulation with phosphoric acid is usually cheaper than with triple superphosphate may seem odd since phosphoric acid usually costs about \$0.15 more per unit. However, it has two economic advantages that outweigh its higher price: greater ammonia absorption capacity and higher concentration. In a typical case it has been estimated that the value of the greater ammonia absorption capacity (7.2 vs. 3.8 lb./unit) is about \$0.13 per unit, and that the value of the higher concentration is about \$0.17 per unit.

Triple superphosphate will readily absorb 3.8 pounds of ammonia per unit of P_2O_5, whereas phosphoric acid will absorb 7.2. What is the extra 3.4 pounds of ammonia-absorbing capacity worth? If valued at the cost of the sulfuric acid that would be needed to absorb this ammonia, the increased ammonia-absorbing capacity is worth about \$0.13 per unit of phosphoric acid when sulfuric acid costs \$24 per ton. If based on the difference in cost between ammonia and ammonium sulfate, the extra ammonia-absorbing capacity is worth about \$0.12 per unit of P_2O_5 in phosphoric acid.

The effect of using phosphoric acid on concentration is illustrated by the fact that wet-process phosphoric acid, ammoniated and dried, yields a 15-52-0 product as compared with about 7-42-0 for ammoniated triple superphosphate. What is this higher concentration worth? One way it can be used is to make higher analysis products. If an equivalent amount of phosphoric acid is substituted for triple superphosphate in the usual formulation for 5-20-20, the grade will be increased to slightly above 6-24-24. The higher grade results in a saving in processing, bagging, and transportation costs per unit of plant food. These savings amount to about $0.17 per unit of phosphoric acid used.

Alternatively the higher concentration of phosphoric acid may be utilized by increased use of ordinary superphosphate. For instance, when 5-20-20 is formulated with phosphoric acid, about 9 units of the P_2O_5 can be derived from ordinary superphosphate as compared with 3 units when triple superphosphate is used. Ordinarily superphosphate is usually the cheapest source of P_2O_5; the saving due to increased use of ordinary superphosphate has been calculated to be equivalent to about $0.18 per unit of phosphoric acid P_2O_5 under typical conditions.

So in comparing phosphoric acid with triple superphosphate, we find it is worth $0.13 per unit more because of its higher ammonia absorption capacity and $0.17 more because of its higher concentration, a total of $0.30 per unit. Since it usually costs about $0.15 per unit more, there is a net saving of $0.15.

For use in solid fertilizers, furnace acid has no important advantages over wet-process acid. It has fewer impurities and therefore gives less difficulty in handling. Also, the ammoniated product has a higher concentration after drying because of the absence of impurities. However, the choice between furnace and wet-process acid for use in solid fertilizers generally is based on economics. Since wet-process acid is cheaper in most locations, it is more widely used. Furnace acid is widely used in the manufacture of liquid mixed fertilizer; wet-process acid is not used for this purpose to a very large extent because of difficulties caused by impurities.

Superphosphoric acid may be used in making solid fertilizers in much the same manner as ordinary phosphoric acid. Since it is highly concentrated, it does not add water to the formulation and therefore can be used in plants that have no dryer or that have only limited drying capacity.

The principal interest in superphosphoric acid is for use in liquid mixed fertilizers. For this purpose it has the advantage if increased solubility of the phosphates formed by ammoniation which enables manufacturers to make higher analysis liquid mixtures or mixtures of lower salting out tempera ture. For instance, 11-33-0 liquid has a salting out temperature well below 0° F. Also, there is considerable interest in using a combination of superphosphoric acid and wet-process acid in making liquid fertilizers. The pyrophosphate content of the superphosphoric acid sequesters the impurities in wet-process acid so that they do not precipitate on ammoniation. Thus, it is possible to make clear liquid fertilizers by ammoniation of the two acids under proper conditions. The proportion of superphosphoric acid required ranges from 10 to 50 per cent (P_2O_5 basis), depending on the characteristics of the wet-process acid and the grade of the desired product. Thus, the use of superphosphoric acid may open up new markets for wet-process acid in the liquid fertilizer field. Unfortunately, difficulties in establishing a satisfactory rail freight rate have handicapped the realization of this objective.

The main advantages of calcium metaphosphate for use in mixed fertilizers are its high concentration and its ability to improve granulation of certain grades. Its disadvantages are its low water solubility and the fact that it cannot be ammoniated in the equipment available in most plants. Due to its high concentration, its delivery cost is often lower than triple superphosphate. Also, it can be used to make high-analysis mixtures with resultant savings in processing, bagging, and transportation costs.

Calcium metaphosphate is used in graulation processes principally in low-nitrogen or no-nitrogen grades. The presence of calcium metaphosphate is helpful in granulating these grades which are usually difficult to granulate. Partial hydrolysis of the calcium metaphosphate forms a sticky material which helps granulation. Grades such as 5-20-20, 6-24-24, 8-16-16, 7-28-14, and 0-20-20 have been made with very good granulation at such low moisture content that little or no drying was required. Some increase in water solubility occurs during granulation and subsequent storage.

Diammonium phosphate is used in formulations for granular and nongranular mixed fertilizers, in dry blends, liquid mixtures, and for direct application. Its delivered cost is usually somewhat higher than an equivalent amount of wet-process phosphoric acid and ammonia. However, it has some advantages that often offset the higher cost. For instance, it can be used in most solid mixing plants without additional equipment. Its use is not limited to those plants that have a dryer. Its use is particularly advantageous in granulation processes in those grades which otherwise would involve a heavy load of chemical reaction in the ammoniator or in which the formulation would otherwise involve a large amount of liquids.

Diammonium phosphate is widely used in dry blends, particularly when substantially complete water solubility is needed such as in fishpond fertilizers and in mixes for addition to irrigation water or for preparation of transplanting solutions.

Availability: Most companies indicated that the supply of triple superphosphate and phosphoric acid was fully adequate to meet the present demand. Some companies indicated that the availability of tank cars was a bottleneck in supplying wet-process acid. More tank cars are being obtained in several cases. It was evident from comments by both producers and users that the use of phosphoric acid in granulation processes was increasing rapidly and was expected to increase further.

Diammonium phosphate is not widely available due to the fact that there are few producers. Superphosphoric acid is not readily available due to lack of a rail freight rate. Some commercial sources indicated that they could supply it, but no prices were given. It is understood that superphosphoric acid is available to fertilizer manufacturers in Canada and that a satisfactory rail freight rate is applicable.

DISCUSSION

Chairman Sauchelli: Thank you, Travis, for a very able presentation of this multiple question. I am sure the information you gave about the new policy of TVA was of great interest to the entire industry.

We have only a brief time for any questions. Are there any specific questions that you wish to ask?

Mr. T. J. Bosman (Federal Chemical Co.): I believe it would be interesting to everybody here if Travis would touch briefly on the great affinity for water of the triple superphosphate when its water of hydration has not been satisfied, and the effect it would have on the analysis of this material if it is held in storage for any length of time.

Mr. Hignett: The high analysis triple super, 54 per cent triple super, picks up water rather readily. That is because it consists primarily of anhydrous monocalcium phosphate, which will absorb water from the atmosphere and form a hydrate. The absorbed water usually does not render it wet or sticky, and usually does not increase the amount of moisture found by AOAC analysis, but it does increase the weight and decrease the grade. So it is necessary to take that into account.

In analytical procedures when weighing out a sample, remember that it is likely to be absorbing water all the time that you are weighing out the sample. It is also likely to absorb water in your plant. So after you have had it on hand for a few weeks, the grade is likely to be lower and the quantity larger than when you got it.

Mr. Carl P. Schumaker (Monsanto Chemical Co.): I am wondering if superphosphoric acid has a similar affinity for water, and what effect this might have on the freezing point of superphosphoric acid when stored for a while.

Mr. Hignett: Superphosphoric acid does absorb water readily on storage. However, most storage tanks are closed, so that is not quite so much a problem. Absorbing water is likely to raise the freezing point. So after it has absorbed, say, 1 or 2 per cent water, it is likely that it will start crystallizing.

Question No. 4—The Use of Nitrogen Solutions Containing Urea, Ammonium Nitrate, Anhydrous Ammonia In Granulated Mixed Fertilizers

J. E. Reynolds, Jr.

THE basic economics of formulating mixed fertilizers with nitrogen solutions in combination with anhydrous ammonia promotes the use of the nitrogen solution which contains the highest fixed to free nitrogen ratio. The nitrogen solution with the highest fixed to free nitrogen ratio also reflects the lowest amount of free ammonia which must be neutralized per pound of solution used. The ability to use this combination of liquid nitrogen materials affords the maximum usage of the most economical source of nitrogen.

Approximately 3 years ago, the ammonia-ammonium nitrate solutions which most closely conformed to these qualifications was either an 83% ammonium nitrate solution, with no anhydrous ammonia and a salting out temperature of 154°F; or a 32% nitrogen solution, often referred to as "R" with a fixed to free nitrogen ratio of 3.83 and a salting out temperature of 93°F; or a 37% nitrogen solution with a fixed to free nitrogen ratio of 1.70 and a salting out temperature of 48°F. The 37% nitrogen solution was selected for our use primarily for its most practical salting out temperature, under operating conditions, and its application to the production of a competitively priced, high quality, 15-15-15 at a reasonable production rate.

High Fixed-to-Free Nitrogen Ratio Solutions

			Dehydrated		
	R	37	37	3XD	11
Total Nitrogen	31.8	37.0	41.4	41.4	41.0
Composition by Weight					
Free Ammonia %	8.0	16.6	19.0	19.0	19.0
Ammonium Nitrate %	72.0	66.8	74.0	65.6	58.0
Urea %	—	—	—	6.0	11.0
Water %	20.0	16.6	7.0	9.4	12.0
Vapor Pressure, Psig @ 104°F	1	1	8	13	10
Salting Out Temperature °F	+93	+48	+64	+35	+ 7
Ratio Fixed N/Free N	3.83	1.70	1.65	1.65	1.63

The use of the 37% nitrogen solution, with an increased liquid phase due to the use of larger amounts of ammonium nitrate in the Davison-Trenton pug mill process, was accomplished with minor adjustments in operating techniques. The operational, quality, and analytical demands of the resulting product conformed to established standards for grades containing less ammonium nitrate. Shortly after adoption of the 37% solution, the total nitrogen content of most nitrogen solutions was increased through creation of a line of dehydrated or lower moisture containing solutions. The fertilizer industry profited through lower delivered nitrogen costs, but the properties of the established solutions were changed. In the case of the now dehydrated 37% solution, a 41.4% nitrogen solution resulted with a 64°F salting out temperature.

The grade pattern and tons of 1-1-1 ratio grades at several of our plants justified the cost for heat exchangers, recirculation lines to and from the storage tank, and heat traced lines to permit the use of this higher temperature salting out solution during the coldest weather. In the case of our smaller tonnage plants where no heated storage and handling equipment existed, for these high salting out solutions, the high fixed to free nitrogen ratio solutions still offered economic advantages. While reviewing the standard nitrogen solutions available, it was noted that an ammonia-ammonium nitrate solution containing 11% urea was almost a duplicate of the dehydrated 37 with 41.4% total nitrogen and a fixed to free nitrogen ratio of 1.63-1.65. One big difference existed, the number 11 solution was characterized by a salting out temperature of only 7°F rather than 64°F for the dehydrated 37. The possibility of using a high fixed to free nitrogen ratio with a 57°F lower salting out temperature warranted an immediate investigation into the use of urea-ammonium nitrate solutions.

Only limited information was available on the quality limitations of urea in pulverized mixed fertilizer but these limits had been established as 50 lbs. of urea per ton of fertilizer. Although even less information was available to establish the limits of urea in graulated mixed fertilizers, the 50 lbs. of urea per ton was arbitrarily chosen at the time. Since then, this limit has proven to be fairly reliable as a rule of thumb. The use of number 11 solution in high 1-1-1 ratio grades reflects a larger percentage ratio of urea to ammonium nitrate than recommended. Later plant production tests of 12-12-12 with number 11 solution in a plant that had been using a +26°F salting out temperature nitrogen solution with a fixed to free nitrogen ratio of 1.25, confirmed that although that granulation was comparable with this solution, the granules did not possess the same hard gritty "feel" associated with the nitrogen solution without urea. Furthermore, the granules later broke down in the pile.

The knowledge of some of the properties of number 11 solution in granulated mixed fertilizers caused interest in changing the specifications of the dehydrated 37 solution through the addition of urea. Although heated storage was provided at our larger granulation installations for a nitrogen solution which salted out at 64°F, some ammonium nitrate crystals did form during prolonged periods of cold weather. These crystals plugged semi-idle lines, caused damage to the flowmeter, pumps, and heat exchanger. It was primarily for the reason of maintenance and convenience that we searched for a solution with a lower salting out temperature. Also, why use a nitrogen solution which required the cost of constant heating when a nitrogen solution is available to provide the same formula savings but requires much less heating and maintenance expense.

Since a zero urea, 64°F salting out solution with a 1.65 fixed to free nitrogen ratio was satisfactory in the production of granulaed mixed fertilizers, and a 11% urea, 7°F salting out solution with the same fixed to free nitrogen ratio would most probably be unsatisfactory due to the large quantity of urea, we naturally became interested in a solution with a urea content someplace between 0 and 11%

Thus, the 6% urea solution came into being and was initially known as 3XD. 3XD solution contains 41.4% total nitrogen, 19.0% free ammonia, 65.6% ammonia nitrate, 6% urea, and 9.4% water. This solution was also designed to maintain a urea content in high analysis grades below 50 lbs. of urea per ton of product.

Plant investigations with 3XD solution revealed the following:

1. The use of 3XD solution was operationally interchangeable with the ammonia-ammonium nitrate solutions in the Davison-Trenton process.
2. The particles were slightly more rounded due to the presence of urea, but just as hard.
3. The quality of the granules in bulk and bag storage was equal to, or slightly better than, comparable grades formulated from ammonia-ammonium nitrate solutions.

The above accomplishments were possible with a solution containing urea, ammonia and ammonium nitrate, and still provided the same economical advantages as the original 37% nitrogen solution. These advantages were *now* possible with a solution which salted out at a temperature of 35°F, rather than 64°F.

The user of a urea-ammonium nitrate solution will first notice the "early" softness of the particles coming from the ammoniator granulator. The operator soon recognizes the importance of adjusting water control techniques and must recognize the difference between water wetness and an increased liquid phase. These features are very closely related, and are often simply described as being related to the time required for the particles to take up the water and cure out. The crystal growth in particles containing urea is slower than that experienced for grades formulated with an ammonium nitrate solution. Caution in drying must be exercised so that the moisture is not driven off before the particle set has occurred. The increased liquid phase from the 3XD solution can result in the formation of larger particles from the granulator, unless adjustments in recycle or wetness are made. A low moisture content in the product is equally important for any grade containing large amounts of either 3XD or 37% solution.

Recently, two urea-ammonia-ammonium nitrate solutions, which salt out at 10° and −17°F, but with a fixed to free nitrogen ratio of 1.40 and 1.43 respectively, have been introduced to our industry. These 6 and 7% urea containing solutions will compete with the ammonia-ammonium nitrate solution at plants that do not have heated storage and have been using solutions of a lower fixed to free nitrogen ratio, such as .90-1.25. Our plant experience with these urea containing solutions in comparison with a 44% nitrogen ammonium nitrate solution containing 23.8% ammonia, which salts out at +26°F, indicates an early adoption of these new 1.40-1.43 fixed to free nitrogen solutions.

The quality of the new product appears to be excellent, the production rate is the same, and definite formula savings exist when comparing the use of these new 6 and 7% urea solutions with more widely used ammonia-ammonium nitrate solutions of lower fixed to free nitrogen ratios.

The use of urea originally as a temperature depressant in ammonia-ammonium nitrate solutions has opened many avenues for more economical formulation. Fertilizer manufacturers were naturally hesitant to use large amounts of solutions containing urea and ammonium nitrate, for fear of urea breakdown when the particles were subjected to drying and an increased hygroscopicity of the product. A place for urea-ammonia-ammonium nitrate solutions has been established in the production of granulated mixed fertilizers with many advantages possible to the company who recognizes its properties and its limitations.

DISCUSSION

Chairman Sauchelli: Bert Tucker, of the Sohio Chemical Company, will discuss our next question; and after that we will have Joe Reynolds, of the Davison Chemical Company, also give his comments.

Bert, do you want to take that question?

(Mr. H. H. Tucker then presented his prepared paper, marked No. 5-D.)

Chairman Sauchelli: Joe Reynolds, do you want to comment briefly on the manufacturer's experience with these solutions?

Mr. Joseph E. Reynolds, Jr.: I think because of the excellent paper that Bert Tucker presented, it might be best that we leave my remarks for the Proceedings, and if you have any questions for Bert and me, maybe we could cover it in that manner.

One comment. We have been using 6 per cent urea, which I think most of you are familiar with, for approximately two years, and we are sold on it and believe it is the way to go. We originally got into this urea ammonia, ammonium nitrate type of solution in a roundabout way. Our original solution was a 37 per cent solution which salted out in the range of 48 degrees Fahrenheit. We went to the high grade solutions, and the salting out temperatures went up to 64 degrees. We had heated storage at our plants which could handle this solution, and we were in pretty good shape with the exception of the extremely cold weather during prolonged periods of time. We did run into some difficulty.

We were also taking a look at other solutions for plants which did not have heated storage, and we came across this No. 11 solution. We were interested in the chemical and physical properties to find that this solution was almost identical in total nitrogen to the dehydrated 37 or your 414. It had the same 6-to-3 ratio, but it had a salting out temperature almost 60 degrees lower than the so-called dehydrated 37.

That was a very interesting solution to us. We didn't know how much urea could be used, and we experimented and found that the No. 11 had too much for our overall needs. Eleven per cent was a little too much urea in mixture with ammonium nitrate. Why not pick something in between? The 6 per cent urea solution looked very good to us.

If there are any questions, maybe this would be the time to terminate my remarks.

Question No. 5—Effects of Urea On Ammonium Nitrate-Ammonia-Water Solutions.

H. H. Tucker

THERE is considerable published information on saturation temperatures and vapor pressures of ammonium nitrate-ammonia-water solutions and on urea-ammonia-water solutions. Little information of this type has been published on four-component solutions containing ammonium nitrate -urea-ammonia-water.

Urea is added to ammonium-nitrate-ammonia-water solutions for the effect it has on the physical properties of the solution and for it's effect on the manufacturing and conditioning of the end product.

Effect of urea on Physical Properties of Nitrogen Solutions

The addition of urea to ammonium-nitrate and ammonia in nitrogen solutions has been shown to reduce the saturation or salting out temperature of the solution. This makes possible the use of higher ratios of salts to ammonia or the increase to what is termed the fixed to free nitrogen ratio. Reducing the saturation temperature may, therefore, permit a reduction in the amount of water.

The increase in the fixed to free nitrogen ratio or the reduction of ammonia reduces the vapor pressure of the solution. The reduction of ammonia reduces the nitrogen content of the solution since an 82% nitrogen material is being replaced by salts which contain 35 or 46% nitrogen. Interaction of all of these factors must be considered in the formulation of nitrogen solutions.

Effect of Urea on the Manufacture of Fertilizers

Work has shown that the addition of urea to fertilizer mixes containing ammonium-nitrate and potassium chloride will increase the plasticity of the material and improve granulation. This increased plasticity is due to the increased solubilities of combinations of urea and ammonium nitrate or ammonium chloride. To prevent excessive plasticity, the amount of urea which can be added to ammonium nitrate containing fertilizers is limited. At 86°F. 100 grams of water will dissolve 242 grams of ammonium nitrate or 133 grams of urea. At the eutectic point of 46 parts urea to 54 parts ammonium nitrate, 100 grams of water will dissolve 1564 grams of combined salts at 86°F. The 242 grams of ammonium nitrate in 100 grams of water will increase the solution volume from 100 to 251. 133 grams of urea in 100 grams of water will increase the solution volume from 100 to 201. The 1564 grams of combined urea-ammonium nitrate at the 46-54 ratio will increase the solution volume from 100 to 1206. This would mean that these salts could be proportioned to increase the volume of one pint of water from 2 to over 12 pints of solution even at 86°F. At higher temperatures the solubilities would be even greater.

The solubility of combinations of urea or ammonium nitrate in water increase gradually with first additions of the second salt. This solubility increases very rapidly as the eutectic combination is approached. For these reasons dry fertilizers containing urea and ammonium nitrate near eutectic proportions may become soggy or plastic at relatively low moisture contents and particularly so at high temperatures.

Properly formulated, the combination of urea and ammonium nitrate can be beneficial in contributing to plasticity at high temperatures for desired granulation and give good hard granules when the excess heat is removed. A low ratio of urea to ammonium nitrate, however, is necessary in order to prevent sogginess or tackiness of the dry end product.

Effect of Urea on the Conditioning of Fertilizers

Work has shown that the addition of urea to fertilizer mixes containing ammonium nitrate and potassium chloride will change the crystal structure of the resultant ammonium chloride from a fern-shaped or dendritic crystal to a cube crystal. This change in shape of crystal formation has definitely been shown to reduce caking or setting of resultant fertilizers. Hygroscopic properties as well as solubilities of combinations of urea and ammonium nitrate or ammonium chloride limit the amount of urea which can be used.

Limits which have been found to be satisfactory in that there is sufficient urea to alter the crystal structure of ammonium chloride and still not be soggy are 20 to 50 pounds of urea per ton of end product made with ammonium nitrate solutions. Limits of 30 to 45 pounds have been found to be even better. Fertilizers containing soluble salts such as ammonium nitrate and/or urea should best be dried below 2% moisture.

To obtain the desired amount of 30 to 45 pounds of urea per ton of end product the quantity of urea in an ammonium nitrate solution is adjusted to the amount of solution to be used. This amount of nitrogen solution is determined by the amount of nitrogen to be obtained from solution and the nitrogen content of the solution. When not over 300 pounds of solution is being used a 15% urea content is acceptable. Where 700-750 pounds of solution are used the urea content of ammonium nitrate solutions is limited to a maximum of 6%

Effect of Addition of Ammonium Nitrate to Urea Ammonia Solutions

Three reasons why the addition of ammonium nitrate to urea ammonia solutions has not developed are: (1) The addition of small amounts of ammonium nitrate to urea ammonia solutions has relatively small effects on the solubility of the combined salt. (2) Urea is less soluble than ammonium nitrate in water or in ammonia water solutions. Urea solutions, therefore, contain more water which may cause over agglomeration and increase the drying operation. (3) There is less need for altering the crystal shape of ammonium chloride when relatively small amounts of ammonium nitrate are added.

Selecting A Solution

It is usually economically desirable to obtain the highest amount of nitrogen possible from solutions. With high nitrogen grades large amounts of nitrogen solutions may be used. The high fixed-to-free ratio of nitrogen in fertilizer solutions for high nitrogen mixed fertilizers is desirable in order to curtail the amount of acid needed to neutralize excess free ammonia. There would be one ideal solution, therefore, for each grade of fertilizer made under each set of conditions. It is usually desirable, however, to compromise on one or two solutions which best fit the range of manufacturing conditions within a given plant and a given area. A low fixed-to-free ratio solution along with a high fixed-to-free nitrogen ratio solution gives good versatility of plant operating conditions with lowest raw materials costs.

Question No. 6—"Have Any Facts Regarding the Characteristics Of Potash For Granulation Been Developed This Year?"

Chairman Sauchelli: This question has been discussed at previous Round Tables, and there have been a number of articles. We have asked representatives of the potash industry to give us any developments or to discuss any new material on this subject which may have been developed during the past year. So we have Mr. H. E. Causey, of International Minerals & Chemical Corporation, Bob MacDonald, of Potash Company of America, and Dick Tayloe, of the National Potash Company, here to give us some information about their new developments. Ed Kapusta is also on this program.

Dick, do you want to start it off?

R. D. Tayloe

THIS will be very short. I talked to Ed Kapusta last night and sort of picked his brains a little bit, so what I have to say is the impressions I have picked up plus what I got from him last night. I won't say how much is from which source.

There is nothing much new in the use of potash to aid granulation in the way of startling facts. Manufacturers have tightened up on their screen specifications somewhat to get a little cleaner products in the granular, coarse, and standard sizes. There has been some trend to follow the recommendations not only of the potash people but of Frank Nielsson earlier this morning, for example, in the use of standard potash in granulation as much as possible. Coarse potash is more or less a crutch. I said this last year. Others have said it. Coarse potash is used to overcome deficiencies in granulation technique. You should develop your technique so you are not dependent upon this crutch, because the use of granular potash in granulated fertilizer is dangerous. It is dangerous because the granular potash is nearly the same size as the granule of fertilizer, and you will wind up with a nonhomogeneous material which will flow apart at the first opportunity. Then the state control man comes around and he doesn't like your 5-20-20 which runs anywhere from 5-22-16 to 5-16-25. You must make that granule homogeneous. That is one of the primary purposes of granulating fertilizer. The way to do it is to use standard potash, fine potash, not granular potash.

There apparently has been some trend toward this practice of using small amounts of coarse potash to help control recycle, to help hold it down, and to use otherwise either the straight standard potash or mixtures of standard and coarse.

I hope this trend continues for two reasons: One is that a lot of people are going to get in trouble with potash analyses, and I will have a lot of trouble trying to find out what is wrong. The other is that, of the potash products, I think there is plenty of standard but the supply of coarse or granular does have a limit. We do not want to see somebody run out who needs it because somebody who did not need it used it all up where he should not have.

One thing is a little curious—the use of granular potash or coarse potash by manufacturers of pulverized fertilizers. Apparently this is done to give a little grainy condition, to improve the storability of the product. Again I say, develop your technique so you make a good product by using the art to full advantage, and don't use granular potash as a prop to cover poor operations.

R. A. MacDonald

THE role of potash in fertilizer mixtures is still the subject of continuing investigation. Several articles have appeared on the value of granular potash as an effective aid to efficient granulation. Articles have also been published touching on the solubility relationships of potash in fertilizers containing ammonium nitrate and ammonium sulfate.

The pronounced shift of fertilizer granulation manufacturers to granular types of potash is ample testimony to the benefits to be derived from use of coarse potash. Therefore, I would like to confine my discussion to a brief examination of some of the known reactions taking place in fertilizer mixtures containing potassium chloride.

The phenomena of ion exchange is of some importance in mixtures since it is generally involved in the caking mechanism.

The reciprocal salt systems of potassium chloride and ammonium nitrate undergo an ion exchange reaction which results in the complete disappearance of either one or both of these salts. The completeness of this reaction is dependent upon conditions during reaction and later storage. It is of interest to note that conditions are always attained where at least a portion of the reaction takes place. Since most fertilizer granulation processes are conducted under low moisture conditions, the extent of reaction is somewhat limited.

If we examine the question, "What can be gained by either completing the reaction or preventing, insofar as possible, any reaction," we will find little data supporting either viewpoint. The literature which I have examined indicates the reaction products, ammonium chloride and potassium nitrate, would produce a fertilizer with better storage characteristics. Conditions necessary to attain this state of equilibrium are not known. The continuing interest in high analysis-high nitrogen fertilizers would indicate need for a rather complete study in this field.

Most fertilizer processes can be classified in the partially reacted field. Recent work by Silverberg and co-workers of TVA on caking mechanisms is of interest since it gives us some insight into the problem. Reactions 100% complete are reported for products of relatively high moisture content, whereas less than 50% reaction occurred in well-dried products. The caking occurring in those products substantially completely reacted should not be given undue weight since it is likely that most of this reaction occurred during storage where the growth of new crystalline phase resulted in masses of agglomerates. Those particles of potash which were not consumed in the reaction were found to be encased with reaction products. This was observed on particles completely incorporated within the granules and on particles unincorporated resulting from incomplete granulation.

Those particles of unincorporated potash appeared to have an unusually bad effect on the caking of the mixture. From this it would be reasonable to conclude that whenever possible an effort should be made to coat the potash particles in the mixture. This is usually possible in those granulation systems where moisture is closely regulated.

Most fertilizer manufacturers will observe a better bag storage on grades which have been stored in bulk for a period prior to bagging. This procedure permits the formation of a somewhat stable solution phase which is not likely to undergo significant change unless it is present to excessive quantities.

The continuing problem of potash analysis in mixed fertilizers should also be mentioned here. Manufacturers are increasingly concerned with widely erratic potash analyses in their mixed fertilizers. Uniform particle size, well granulated fertilizers, will tend to reduce the variations. It will not, however, compensate for defective analytical determinations. Potash is a rather difficult chemical determination. The gravimetric method is tedious and involved, although the flame photometer appears to be simple and rapid. The chloroplatinate, or gravimetric method, should be closely followed since shortcuts risk inaccuracies. The flame photometer is sensitive to the source of potash and standards should preferably be compounded from fertilizers approximately equivalent to the grade being tested. Only reliable chemical analysis can serve.

H. E. Causey

WE think that the best way to answer the above question would be to review what was discussed by this same group last year and perhaps to project at this time a complete history of the new look as to the mesh size of a particle of muriate of potash.

A typical screen analysis of standard muriate of potash of ten to fifteen years ago was the following:

Mesh	% Cumulative
6	.2
8	1.2
10	2.0
14	2.6
20	11.0
28	33.8
35	56.6
48	75.2
65	85.4
80	88.0
100	91.8
200	98.0
–200	2.0

Most of the domestic production was merchandised as standard, some, however, was offered for a direct application material of a larger granular size, a typical analysis being the following:

50% Granular

Mesh	% Cumulative
6	.4
8	7.0
10	39.4
14	72.6
20	86.6
28	92.0
35	94.6
48	96.4
65	97.6
80	98.0
100	98.5
200	99.6
–200	.4

Beginning the new era of granulation, potash producers have been faced with the problem of supplying the demand for various particle sized material. Some variables, such as using a TVA ammoniator, a pug mill, or a standard batch mixer, has established the need for different particle sized muriate. Most domestic producers are offering a material similar to the following screen analysis:

1. Granular

Mesh	% Cumulative
6	15
8	40
10	75
14	96

2. Coarse Muriate

Mesh	% Cumulative
10	9
14	60
20	82
28	95
35	99

3. Standard

Mesh	% Cumulative
20	3
28	28
35	62
48	81
65	92
100	98

With the above classified products it becomes optional with the buyer as to his selection.

There is a definite trend with all manufacturers to use a minimum amount of oversize potash, however, some processes demand a size larger than standard to maintain the through-put tons per hour.

Question No. 7—What are Formula Recommendations for Good Granulation of a 3-2-2 Ratio Material?

John M. Daniel, Jr.

THIS ratio, which would include such grades as 15-10-10 and 12-8-8, would lend itself to the use of low free ammonia solutions either with or without urea. Typical ones which could be used are Nitrogen Solutions 450 (25-69-0), 420 (19-66-6), 440 (22-66-6), and 430 (20-68-6). The solution selected would depend largely on climatic conditions in order to avoid salting out.

There are two basic sets of conditions which each manufacturer must evaluate for himself. The first is where maximum product tonnage is not mandatory and large amounts of recycle can be tolerated. The second is where the maximum production rate is necessary and recycle must be minimized.

Let's consider the first set of circumstances. By the use of preneutralization it is conceivable that all the nitrogen could be obtained from solution in 15-10-10 and 12-8-8. High recycle rates would probably be necessary. In order to take advantage of the ammonia absorbing capacity of the phosphatic materials it would be necessary to split the solution feed between the preneutralizer and the ammoniator. This entails expenditures for an additional flowmeter and pipe plus giving the operator one more liquid metering stream to control. For plants where anhydrous ammonia is available this material could be metered into the ammoniator for the phosphate to absorb. Each company must evaluate whether the tonnage required justifies the expenditure for additional equipment. Products made all from solution would have high ammonium nitrate contents and would require drying to very low moisture contents and the addition of coating agents to preclude caking.

In the second set of circumstances where a high production rate is necessary, it would be preferable to use solid ammonium sulfate. This would eliminate splitting the solution feed and the expenditure for additional equipment. Drying of the product would be less critical and the amount of coating agents could be reduced. Formulating with solid sulfate will in most cases give a higher materials cost per ton. This must be balanced against labor and other operating costs per ton if large recycle rates are used.

We have made no pilot plant studies on grades with this ratio as yet and 12-8-8 is the only one we have made in commercial scale equipment. Pilot plant studies will be made in the near future.

Elmer Perrine

MAKING these grades is rapidly advancing the fertilizer industry into chemical processing and away from the conventional methods of manufacturing fertilizer. The economics, equipment design, safety and even the training of personnel for making some fertilizer grades include much that is common to the chemical industry. These points are strongly in evidence where the grades are granulated and the plant is using ordinary ingredients with fertilizer equipment rather than use the morte exotic products that enter the market.

The final cost of a ton of high nitrogen fertilizer is influenced by many things beyond the original cost of the nitrogen. The combining of ammonia with superphosphate fixes the lowest cost nitrogen in fertilizer and the superphosphate should therefore be used at maximum efficiency.

With 100 per cent retention of the amount applied 20 per cent superphosphate should react with as much as 5.5 pounds of ammonia per unit of P_2O_5. Triple superphosphate should react with as much as 2.5 pounds of ammonia per unit of P_2O_5. Formulation should therefore use the maximum amount of 20% superphosphate for its influence on the cost of nitrogen as well as for the usually lower cost of the superphosphate. One pound of ammonia reacts with 3.1 pounds of 66°Be sulfuric acid (93%). The industry usually formulates about 7.2 pounds of ammonia for each unit of P_2O_5 in phosphoric acid.

A pound of ammonia reacted with sulfuric acid produces over twice the B. T. U.'s of heat that is produced when the ammonia reacts with 20% superphosphate. In granulation this added heat is often well worth the cost of some acid beyond the exact needs of total neutralization.

The economics of formulation sometimes get relegated to a subordinate place in the struggle to fit the ingredients into the grade within the 2000 pounds limit of a ton, obtain maximum heat, include enough ammonium nitrate or urea or both for easy granulation, and meet the several fancies of salesmen, agronomists, and the customer.

Within reasonable limits for the granulation of fertilizer that ammoniating solution which contains the least free ammonia for unit of total nitrogen will be the most economical. The man who does much formulating can simplify his work by using a table which shows this ammonia-to-total nitrogen relation. One nitrogen solution that is widely used in granulation as well as in pulverized fertilizer contains 10.8 pounds of ammonia per unit of total nitrogen. Another solution, also widely used, contains 8.9 pounds. These factors call for detailed study of heats, weights, cost of sulfuric and phosphoric acid, and liquid phase influence on granulation. When all of the ammonia from one unit of nitrogen is neutralized with acid this can make the nitrogen from one solution cost more than may be necessary in some cases.

The last few units of nitrogen in one considered formula involved 30 pounds more dry weight for each unit of nitrogen from one solution than from another when all of the ammonia was to be reacted with 20% superphosphate. The fact that the heavier result included .6 more units of P_2O_5 is not the main problem in 2-1-1 and 3-2-2 grades.

Anhydrous ammonia used with sulfuric acid has its place even in granulation but the need for some additional ingredients such as ammonium nitrate to insure granulation seems to limit this practice quite sharply.

There is much more involved than merely the amount of acid used, but the problem of safety, of holding analysis, and of air pollution often become serious when great amounts of sulfuric acid are used directly in the fertilizer mass in conventional mixers. For some time the ingenuity of men and the capacities of equipment have been taxed by the higher 1-1-1 grades. The 2-1-1 and 3-2-2 grades of high analysis demand careful measuring of every step in the process.

Sulfuric acid at the rate of 370 pounds has been used and even more is anticipated for good granulation and economy in the 2-1-1 and 3-2-2 grades. It is understandable that some operators may look at this development with jaundiced eyes after their experience with much less amounts of acid in conventional processes.

A development that was generally described before the 1957 meeting of the Fertilizer Industry Round Table favors the use of all of the acid being mixed with the appropriate amount of nitrogen solution in a separate operation prior to introduction into the mixer that handles the ammoniation of the superphosphate and the other normal mixing operations.

This process isolates the acid and nitrogen solution action and permits controls that have proven satisfactory in operations that are quite routine in the chemical industry.

DISCUSSION

Mr. Elmer C. Perrine: Man seems to be a pretty restless sort of animal. Woman, too. We buy a brand-new chrome-plated car for a wife and put it out on the street to make our neighbors envious and, damn it, the next morning she wants us to put a motor in the thing so she can drive it. That is what we are doing in the fertilizer industry. We do a pretty good job of making pulverized fertilizer, and then we come along and want to up the grades or we want to solve all the problems of conditioning. So we granulate. Everybody is happy then.

We found that we ought to dry down to 3 per cent moisture, and that was swell. That was only about three years ago. That lasted for one year. Then we went to 2 per cent moisture. Now we think 1½ might do it, and many of them talk of going to 1 per cent. I have seen some rather serious trouble arising from going to ½ or 1 per cent because 1 per cent seemed not to be adequate.

The things we are doing are heading us into the need for better conditioning which looks like coating. I have seen formulas rather recently and a considerable tonnage made of a material which, in addition to something like 400 pounds of ammonium nitrate in from a solution, had an additional 400 pounds, pretty close to 800 pounds of ammonium nitrate in that fertilizer. We see anywhere from 400 to 500 or 600 pounds of ammonium nitrate combined with from 25 to 50 pounds of urea in there that we want to get conditioned. It isn't much good unless we achieve the thing that we set out to do, high analysis with good condition.

Frank Nielsson showed us why we may have to coat. Coating alone will not do it all. It will not relieve us of doing a good job of drying and of cooling. We still have to do that before coating will be worth anything.

This all leads up to a confession that I do not know much about coating. I think maybe the reason that coating has not been developed is a testimonial to the good job the industry has done in achieving conditions in other ways, drying and cooling. We have reached pretty much the limit of the ability to dry. I do not know how much drier you can get than ½ of 1 per cent, or what good it would do if you did it. I think we can do a better job of cooling.

With your indulgence, I shall ask our good friend John Hardesty to give a little discussion on that. I think perhaps he is a man who does know something about it.

John, will you take over, please.

Chairman Sauchelli: It is always a pleasure to have John Hardesty, of the United States Department of Agriculture, with us. He always has been very helpful.

Mr. John O. Hardesty: I think this problem was nicely discussed last year. About all I can add is that we do have a reference to some work which was done in our laboratory a few years ago entitled, "Relative Effectiveness of Granule Coating Agents." That means coating agents for granular materials, of course. It appeared in *Agricultural and Food Chemistry,* volume 4, page 132, in 1956. Mr. Kumagai did, I thought, some very nice work there in distributing various coating agents on granular fertilizers, mixed fertilizers—10-10-10 was, I believe, the standard mixture—that were very cantankerous from the conditioning standpoint.

In that work he found that the siliceous materials, SiO_2, calcium silicate, any siliceous materials which are inert, very finely divided, and having a very low bulk density, were the types of materials which gave him the best conditioning effect on granular materials. That is, a good coverage for the granular material, a good coating agent, is what he was after. The siliceous materials seemed to do that job very well as long as they were of low bulk density and of very small particle size down to just a few microns in diameter.

That is about all that I can give you, I believe, Elmer.

Chairman Sauchelli: Thank you, gentlemen.

You all got the reference. That was a very comprehensive study which was made at Beltsville by Kumagai and John Hardesty. If you do not have that article, you should get it and have it for reference.

(Brief recess.)

Question No. 8—Can "Spent" Sulphuric Acid Be Used Successfully In a Continuous Ammoniator?

T. J. Bosman

WE have used and are using spent sulphuric acid at our Danville Plant in acidulating phosphate rock. We have never used it in ammoniation, so anything I say about this will only be an opinion.

In acidulation this is far from an ideal product. It is hard to get an accurate reading on your hydrometer. When you do it doesn't check with the chemical determination. The differences between hydrometer reading and chemical determination vary between different lots so that it is hard to apply a correction factor. The Baumé reading will run from 0.5 degree to 1.5 degrees higher than the chemical determination shows. The tars that cause this trouble also mess up all your equipment. We feel this would keep you from reading your instruments correctly in granulation.

Another point that must be taken into consideration is a large amount of spent acid is alkylation acid, and will contain some detergents, which in turn may affect your granulation.

Due to our acidulation troubles, we have felt it would be better to keep away from spent acid in our granulation process. This theory has been concurred in by people who have had experience with spent acid. Mr. Jim Seymour, now with Monsanto, who was previously with Illinois Farm Supply has had experience with this material, and his opinion is to leave it alone if virgin acid is obtainable.

Question No. 9—What are the Basic Principles in Choosing the Correct Nitrogen Solution?

C. E. Franklin

TODAY there are in excess of 40 different ammoniating solutions available to the fertilizer industry for the manufacture of mixed fertilizers. As a result of these many solutions, most of which have been introduced during the past three years, the question is often asked, "How does one choose the proper ammoniating solution for his operation?"

It should be realized that there are many different types of fertilizers produced throughout this country today. Fertilizers are produced in mixing plants with various types of manufacturing equipment; batch mixers and continuous ammoniators, some with drying and/or cooling facilities, and many other process variations.

Different fertilizer manufacturers may use different raw materials, which may influence the formulations, such as one or more of ammonium sulphate, anhydrous ammonia, sulfuric acid and/or phosphoric acid. Climatic conditions vary with geographical locations and the season in which fertilizer may be produced.

As a result of these many variables in fertilizer production the nitrogen solution producers have attempted to offer the fertilizer mixers in their marketing area a choice of solutions which will best fit each mixer's individual needs.

The ammoniating solutions available can possibly best be described as having three sets of characteristics which classify them.

1. The first major characteristic is the type and content of the fixed nitrogen, which is usually in the form of ammonium nitrate. urea, or a combination of these two soluble salts.
2. The second characteristic is the fixed to free ratio which is the ratio of nitrogen from salts to nitrogen from the free or neutralizing ammonia in the solution. This ratio gives an indication of the soluble salt content and the free ammonia which must be neutralized. The fixed to free ratios are usually divided into three groups; low, medium and high. The low group has a fixed to free ratio less than 0.8 to 1. The medium group has a fixed to free ratio in the range of 0.8 to 1, to 1 to 1, while the high group has a ratio greater than 1 to 1.
3. The third characteristic of a solution is its water content. The water content of a solution can range from as low as 6% in the dehydrated solution to 18% in regular ammonium nitrate solutions and up to 30.7% in the urea solutions.

One additional and very important characteristic, which in some cases must be considered, is the crystallization temperature, or the temperature at which the solution will salt out. This crystallization temperature is, however, dependent upon each of the above mentioned characteristics, type of soluble salt, ratio of soluble salts to ammonia content and per cent water in the solution.

The first step in selecting an ammoniating solution, is to determine which type of ammoniating solution is best for your plant. The ammonia-ammonium nitrate solution, the ammonia-ammonium nitrate-urea solution, or the ammonia-urea solution. All have their own individual properties. In the manufacture of granulated fertilizers, general experience indicates that better granulation of most fertilizer grades can be achieved with the ammonia-ammonium nitrate solution. This is due primarily to the greater solubility of ammonium nitrate, thereby increasing the liquid phase, or the plasticity of the fertilizer in the ammoniator, which is necessary to achieve good granulation.

In the production of non-granular fertilizers, which are low in nitrogen content and high in potash, as are most of the grades in the southeast, an ammonium nitrate solution containing a small percentage of urea, 10 to 15 weight per cent is used with good success. Twenty to forty pounds of urea in a ton of fertilizer will change the crystal structure of ammonium chloride crystals to give a better conditioned product. However, care should be taken not to exceed 40 pounds of urea in a ton of fertilizer containing ammonium nitrate, as the increased concentration will cause the product to become excessively hydroscopic.

After selecting the type of supplemental nitrogen desired in the ammoniating solution, the next step in the selection is to determine the fixed-to-free nitrogen ratio requirement; low, medium or high ratio. In this selection, consideration must be given to the several following factors:

1. The need for ammonia for heats of reaction and the neutralization of the phosphate materials. This is primarily true of the low nitrogen grades.
2. The maximum ammonia that can be reacted with the phosphate materials if sulfuric or phosphoric acid is not used. Care must be exercised not to over-ammoniate the phosphate materials which can lead to phosphate reversion and/or nitrogen losses.
3. In formulations in which sulfuric acid is used, the more ammonia that is present, as in the low fixed-to-free nitrogen solutions, the more sulfuric acid that is required to neutralize the excess free ammonia. This increases the heat developed in the mixer which may be beneficial in low nitrogen grades but can lead to operating difficulties in the higher nitrogen grades. It must be remembered that the increased use of sulfuric acid due to excess ammonia in a solution also increases the cost of the formulation.
4. If anhydrous ammonia is used in the process, a high fixed-to-free ratio is desired, i.e., a solution with the lowest possible ammonia content so that as much low cost anhydrous ammonia can be used in the formulation as possible thereby reducing the cost of the formulation.
5. In granulation processes the soluble salt required to achieve the proper liquid phase must be taken into consideration. A liquid phase is necessary to give the plasticity which is necessary to get good granulation. Other factors also influence the liquid phase, such as moisture and temperature, however; the soluble salt content, whether ammonium nitrate or urea, is one of the most critical in producing the correct degree of plasticity. The solution with a too low fixed-to-free ratio may result in too little plasticity and will result in insufficient granulation, while a solution with a too high fixed-to-free ratio may give too much plasticity resulting in large amounts of oversized material being formed in the ammoniator.

After each of the above points is taken into consideration, it will usually be found that a low nitrogen fertilizer grade will require a solution with a low fixed-to-free ratio, a medium nitrogen grade will require a medium fixed-to-free ratio, and the high nitrogen grades, a high fixed-to-free ratio. One exception to this generality is when anhydrous ammonia is used to supplement the nitrogen solution, in which case a solution with a high fixed to free ratio is the most desirable.

The third step in the selection of a nitrogen solution is the water content of the solution. In recent years a large number of dehydrated solutions has been introduced to the market which have a moisture content in the 6 to 7 per cent range. The dehydrated solutions have definite advantage in the granulation of the higher nitrogen grade which may tend to overgranulate in that they reduce the amount of recycle required to control the liquid phase in the ammoniator. Another important factor is that fertilizer made with dehydrated solutions require less drying, as the fertilizer comes from the ammoniator with a lower moisture content. The dehydrated or concentrated solutions also have the advantage in freight savings in that the mixer receives more nitrogen per freight dollar due to the lower water content.

In some grades the solution with higher water content is desired to give the required moisture for the proper liquid phase. Also this type of solution is desired in some batch type operations as the dehydrated solutions may produce too much heat, resulting in nitrogen losses, while the increased water in the regular solutions serves to cool the batch as the water is evaporated by the heats of reaction.

If the mixing operations are to be conducted in cool or cold climatic conditions, consideration must also be given to the maximum crystallization temperature allowable. The crystallization temperatures of the many solutions offered vary over a very wide range —from minus 50° F. to above plus 50°F. Many of the popular solutions have crystalization temperatures in the 10° to 30° F. range, which can be particularly troublesome in cold weather operation and should be avoided during the cold seasons unless proper facilities for handling these solutions are installed. The facilities required are insulated and/or heated solution lines and heated storage facilities.

After all these factors have been taken into consideration, several compromises probably will have to be made before selecting the one ammoniating solution which will give you the best product at the desirable operating conditions at the most economical formulation cost. Since it is impractical to use a different solution for each grade produced, the solution selected should be one that nearly fits the majority of the requirements for the majority of the tonnage to be produced. It may be that over the full year's operation, a fertilizer mixer may wish to settle on the use of two ammoniating solutions, a warm weather solution and a cold weather solution.

Grant C. Marburger

CONFUSION in ammoniating solutions is so common in the fertilizer industry today, and yet they are so simple. The real meaning of this paradox is not appreciated until it is translated into dollars. Like oil and water, which will not mix together, good economics and wrongly used solutions can never sit side by side in anybody's plant. One to four dollars a ton for 10,000 tons production represents a figure that many of us in this room today would trade for our salaries. There are cases where this amounts to more than $100,000 for a single company, but let's first get into some basic principles.

Nitrogen solutions in general are made up of free ammonia, ammonium nitrate, urea and water. The free neutralizing ammonia is the constituent that reacts chemically in all fertilizer production, combining with superphosphates or phosphoric acid. The ammonium nitrate or urea constituents can be classified as fixed nitrogen. They are non-volatile or stable compounds at ordinary temperatures. The amount of solution that can be used in the production of a grade of fertilizer is limited by the capacity of the superphosphates or phosphoric acid to react with the free ammonia in the solution. or saying it another way, the free ammonia content of the solution determines the amount that can be used. The balance of the nitrogen is usually made up from sulphate of ammonia, a high cost material, or additional solution is used and sulphuric acid is added to combine with the excess free ammonia, forming sulphate of ammonia in the mixer.

Based on these basic facts of chemistry, the one most important characteristic in choosing a nitrogen solution is its free ammonia content, and this property becomes the first basis to use when selecting a solution. It must be expressed in some way as a ratio of free to fixed nitrogen in order to become usable in comparing one solution against another. An easy way of expressing this can be made in terms of ammoniation rate. This is best illustrated by a slide. Figure #1 will first explain the solution nomenclature system used throughout this discussion.

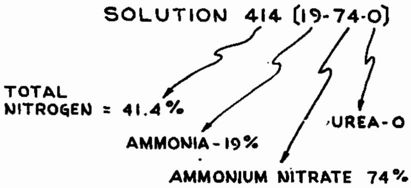


Figure 1

Solutions are named using the nomenclaure system adopted by the industry in September of this year through the efforts of the National Plant Food Institute. For those of you new to this nomenclature, the first number gives the total nitrogen content of the solution with the decimal point omitted. The figures inside the brackets give the percentage content of ammonia, ammonium nitrate and urea in the solution to the nearest whole num-

Figure 2

	Ammoniation Rate*						
Fertilizer Ratio	Spensol 414 [19-74-0]	Spensol 440 [22-66-6]	Spensol 448 [25-69-0]	Spensol 471 [30-64-0]	Spensol 490 [34-60-0]	Spensol 506 [43-45-0]	Spensol 530 [49-36-0]
1-1	9.2	10.0	11.2	12.8	13.9	16.8	18.5
1-2	4.6	5.0	5.6	6.4	7.0	8.4	9.3
1-3	3.0	3.3	3.7	4.3	4.6	5.6	6.2
1-4	2.3	2.5	2.8	3.2	3.5	4.2	4.6

* All units nitrogen from Spensol

ber, in that sequence. For example, Solution 414 (19-74-0) has a total nitrogen content of 41.4 percent. This nitrogen is derived from a combination of 19 per cent ammonia, 74 percent ammonium nitrate and 0 percent urea.

Figure 2 shows a table of ammoniation rates which has been compiled as an aid in choosing a nitrogen solution with the proper free to fixed nitrogen ratio for the grade to be manufactured. Its sole purpose is to provide a birdseye view of the free ammonia content comparison between different solutions. If a 1-1 ratio fertilizer is to be produced, it can be seen from the figure that Solution 414 (19-74-0) would give a 9.2 degree of ammoniation, if all units were obtained from solution, whereas Solution 530 (49-36-0) would yield 18.5. The choice would be the solution closest to the ammoniation rate that can be achieved, generally 4 to 5 percent, consequently Solution 414 (19-74-0), yielding 9.2 degree of ammoniation would be chosen. On the other hand, if a 1-4 ratio is to be produced, the first solution would allow an ammoniation rate of 2.3 and the latter 4.6.

Figure 3

	Free N ÷ Total N %
Solution	
318[8-72-0]	20.6%
414[19-74-0]	37.8%
440[22-66-6]	41.1%
448[25-69-0]	45.9%
471[30-64-0]	52.4%
490[34-60-0]	57.1%
506[43-45-0]	69.3%
530[49-36-0]	76.0%

The latter would be chosen, since it is closer to a 5 degree ammoniation rate, unless additional factors yet to be considered in the selection of solution should rule it out.

Another excellent way of comparing the free nitrogen content of solutions is illustrated in figure 3. First, notice the column at the left. The free nitrogen ratio can be observed from the name alone by mentally comparing the ammonia content and the ammonium nitrate content. In the case of urea containing solutions, the urea must be added to the ammonium nitrate content, and this total compared to ammonia. The column at the right is a tabulation where this ratio has been calculated, saving the mental comparison. The free ammonia nitrogen is expressed as a percent of total nitrogen. The larger this number becomes, the higher the free ammonia content of the solu-

Figure 5

12-12-12

Spensol 440 (22-66-6)	386	@ .0287	$11.08
Sulfate Ammonia	339	.0205	6.96
H_2SO_4	115	.0135	1.55
Potash	400	—0—	—0—
Triple	306	.029	8.87
Normal	497	.009	4.47
	2043		$32.93
Spensol 490 (34-60-0)	303	.0334	$10.12
Sulfate Ammonia	444	.0205	9.10
H_2SO_4	173	.0135	2.34
Potash	400	—0—	—0—
Triple	393	.029	11.40
Normal	300	.009	2.70
	2013		$35.66

Spensol 440 (22-66-6)	546	.0287	$15.67
H_2SO_4	223	.0135	3.01
Potash	400	—0—	—0—
Triple	213	.029	6.18
Normal	712	.009	6.41
	2094		$31.27
Spensol 490 (34-60-0)	490	.0334	$16.37
H_2SO_4	366	.0135	4.94
Potash	400	—0—	—0—
Triple	283	.029	8.21
Normal	553	.099	4.98
	2092		$34.50

Figure 6

5-20-20

Spensol 440 (22-66-6)	107	@^{s}.0495	$3.22	
Anhy. Ammonia	65	.0287	3.07	
Potash	667	—0—	—0—	
Triple	614	.029	17.80	
Normal	593	.009	5.34	
Steam	135	.001	.13	
	2181		$29.56	Cheapest
Spensol 506 (43-45-0)	198		$ 6.80	
Potash	667		—0—	
Triple	617		17.90	
Normal	580		5.21	
Steam	135		.13	
	2197		$30.04	(+$.48)

5-20-20

Anhy. Ammonia	122	$ 6.04	
H_2SO_4	135	1.83	
Potash	667	—0—	
Triple	676	19.60	
Normal	441	3.97	
	2041	$31.44	(+1.88)

tion. A graphical presentation shows this principle more clearly figure 4. The graph shows the nitrogen derived from ammonia in white and the fixed nitrogen in green. Anhydrous ammonia is listed to show at a glance how the various solutions relate to anhydrous which, of course, contains only ammonia nitrogen.

If the plant superintendent wants a high free ammonia solution for a given need, say a 1-4 or 1-3 ratio, he would select a solution with a high percentage free to total nitrogen. For a 1-1 or 1-2 ratio, where a high percentage of fixed nitrogen is desired, he would select a low number, after taking into consideration salting out temperature.

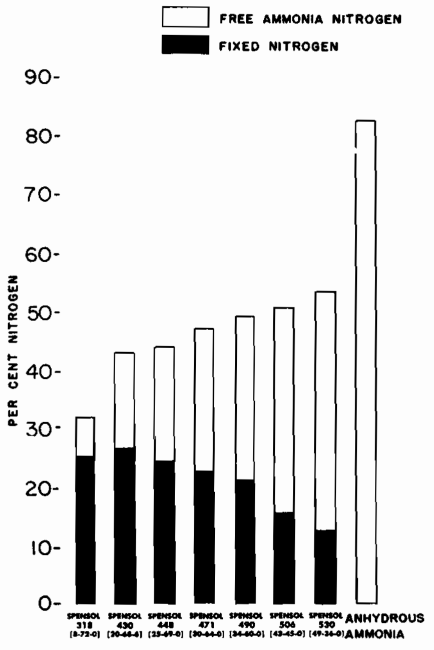


Figure 4

In this ratio method of comparing solutions, it is to be noted from the physical properties listed in the tables that as the percent of free to total nitrogen gets larger, the salting out temperature decreases and the vapor pressure increases. Some new developments in solutions whereby the salting out temperature is decreased, voids this general rule.

The selection of a solution based on the free nitrogen content principle becomes important from an economic standpoint. The next few (figures 5, 6, 7) illustrate the effect that the correct solution choice can have on reducing formula costs. Formulas illustrating grades 12-12-12 and 5-20-20 have been used, as most other ratios will fall between these two.

If 12-12-12 is to be produced with a high free ammonia solution, the formula cost increases because more sulphuric acid is required and more triple superphosphate must be used. Since sulphuric acid is not a plant food, its cost is an added expense, and the formula cost rises as triple is increased since it is more expensive than normal superphosphate. The actual spread in cost depends entirely on delivered raw material prices at a given location and cannot be guessed in advance. Only a comparison of the complete formulas will evaluate the economics under consideration.

For a plant equipped to use anhydrous ammonia, the choice of solution is simple. That with the lowest free ammonia content would be chosen, if facilities are present to prevent salting out. When such facilities are not available, the lowest free ammonia solution with a tolerable salting out temperature is the proper one.

With anhydrous ammonia available to the plant, only one Spensol is needed for all grades manufactured. By the addition of ammonia, you are in effect making your own solution in situ. Using a combination of anhydrous ammonia and the lowest free ammonia solution that can be used without salting out problems for the climate involved, gives maximum flexibility by enabling the plant superintendent to tailor-make the right combination for any and all of the grades he produces. Plants so equipped eliminate the necessity to handle several solutions. The handling and use of anhydrous ammonia presents some problems, but it is being used successfully at many plants. It is a concentrated nitrogen material and a small error in weighing or measuring shows up in the product analysis. Being a gas at ordinary pressure and temperature makes it harder to hold in the reactor. In other words, more exacting conditions are required to prevent ammonia loss. There is considerably more advantage to using anhydrous ammonia in a continuous ammoniating system than in a batch operation. Losses in handling and metering are also considerably less.

Once the proper solution has been selected from an ammoniation rate basis, other principles must be considered before making a final selection. The fundamentals are simple and can be properly evaluated if all presently known technology is utilized in making their choice.

The salting out temperature, of course, must be appropriate. Low free ammonia solutions, such as those used in making 2-1 and

Figure 7

	5-20-20		
Spensol 506 (43-45-0)	198	$6.80	
H_2SO_4	135	1.28	
Potash	667	0	
Triple	724	21.00	
Super	337	3.20	
	2061	$32.28	($2.72)
	5-20-20		
Anhy. Ammonia	122	$6.05	
Potash	667	0	
H_3PO_4	390	15.60	
Normal	950	8.55	
	2129	$30.20	(+$.64)
Spensol 506 (43-45-0)	198	$6.80	
Potash	667	0	
H_3PO_4	140	5.60	
Triple	448	13.00	
Normal	685	6.15	
	2138	$31.55	(+$1.99)

1-1 ratios are involved with this problem. Ammonia is a solvent for ammonium nitrate and/or urea, so low free ammonia means high salting out temperatures. High free ammonia means high vapor pressure and should not be used unless the equipment is capable.

Recent solution changes have greatly improved the salting out problems formerly encountered with low free ammonia solutions. The addition of urea in small quantities, forming proper combinations with ammonium nitrate, will reduce salting out temperatures. Notice (figure 8) the drop in salting out temperature from 64° to 35° between the first two solutions, both having 37.8 percent free nitrogen, and the same total nitrogen content. Or the last solution which has a small increase in free nitrogen, 37.8% to 41.1%, and yet drops the salting out temperature from 64° to −17°. Six percent urea is the additive that has depressed this temperature, which is the reason for its presence, yet the amount of urea is not sufficient to cause the fertilizer to be more hygroscopic.

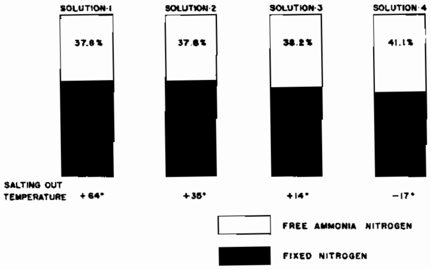


Figure 8

The physical condition of the fertilizer must be considered in the selection of a Spensol, and the amount of ammonium nitrate and urea may or may not cause the fertilizer to have poor physical properties. There is little standardization in the fertilizer industry insofar as process equipment and operating conditions are concerned. Knowing just how far to go on the use of ammonium nitrate and/or urea is a matter of judgment, and the knowledge of the individual plant's set-up is the only possible way to exercise good judgment. In granulation, many plants have dryers without sufficient capacity to dry to a low enough moisture at the production rate they wish to run. To produce a product that is free from bag cake, the amount of ammonium nitrate and/or urea that can be tolerated is governed by the moisture content of the finished product.

The water content of the solution is important. In granulation the use of "dehydrated" solutions on high nitrogen grades is automatically recommended. The low water solutions reduce the excess liquid phase encountered in these grades, which in turn will serve either to reduce recycle, if it is used for control, or to reduce the amount of sulphate of ammonia used in the formula. These solutions offer the additional advantage of freight savings because of their greater concentration. Non granular fertilizer, produced in plants without mechanical dryers, are critically dependent upon the moisture content of the finished product. Since most of the moisture introduced in their production comes from superphosphate and ammoniating solutions, the water content of the solution becomes important.

In recent years, the choice between urea and ammonium nitrate solutions, or combinations thereof, has become important in manufacturing non-granular fertilizers. The only purpose of the urea in the solution is to change the crystal habits of ammonium chloride and potassium nitrate in the finished product, to reduce bag set or bag cake. On the other hand, the presence of urea in combination with ammonium nitrate makes a more hygroscopic mixture than either ammonium nitrate or urea alone. Also, the urea will decompose in storage if the fertilizer is allowed to go to the pile too hot. Urea decomposes at temperatures above 120°F, and releases free ammonia. The ammonia reacts with the phosphates causing reversion, and the beneficial effect of urea to reduce caking in non granular fertilizer is lost. Straight urea solutions do not form objectional salt crystals, but their high water content, plus the hazard of urea decomposition in storage, restricts the effectiveness of these solutions.

Despite the high pressure equipment involved in their use, high ammonia solutions can satisfactorily produce good mechanical condition in non granular fertilizers. Sufficient heat is created by the free ammonia to lower the moisture content to a safe level, and a reduction in hygroscopic salt content is obtained.

In general, the selection of solutions for non-granular production is more difficult than granular. Operating conditions vary more from plant to plant and the curing factor is brought into play. The mixer temperature has a great bearing on the physical condition of the finished product. The retention time in the mixer, amount of ammonium sulphate used, storage temperature, size of storage pile and numerous other things affect the quality of the product. Product moisture content and curing time are the two factors more important than selection of the proper solution, or the formula used.

Very little mention of economics has been made in this discussion, yet the principles described are all aimed in the direction of obtaining savings through the correct choice of ammoniating solutions.

No discussion on this subject would be complete without including the question so frequently asked, with great justification: Are so many solutions necessary? The answer: No. Progress in the development of fertilizer technology has been gradual, just as the engineering developments in automobile manufacture. The auto industry comes out with new models each year in which they combine the good features of the old with new and better features. New solutions have been added to meet the needs of new technology in formulating and processing. When the new technology has been completely adopted, some of the old solutions can be dropped from the list. Just as the auto industry has to continue making parts for old vintage cars, the nitrogen industry will continue making solutions until manufacuring plants are altered to the latest technology.

This point is illustrated in figure 9. In this figure we are looking at most of the solutions produced by our company. We are also looking at them on the basis of physical properties, which have been graphically expressed for easy

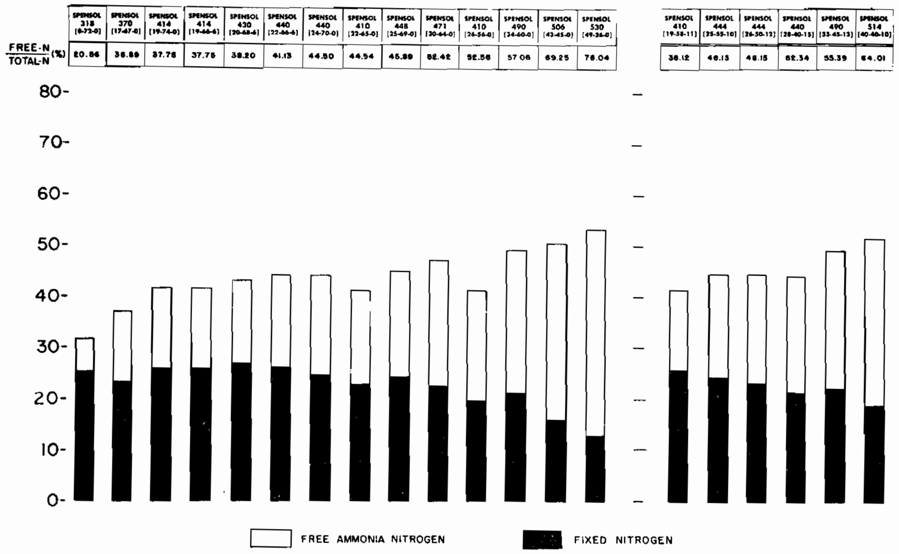


Figure 9

comparision, and when viewed from this aspect it becomes apparent that duplications exist and some of them do not fill a real need. Notice the small deviations between some of the solutions. A specific example can be seen in 440 (24-70-0), 410 (22-65-0) and 448 (25-69-0); and another in 370 (17-67-0), 414 (19-74-0) and 414 (19-66-6). These minute differences are not detectable in plant operation. In other words, some of them could be dropped which would further simplfy the purchasing agent's problems.

Summary

(1) The basic principles of choosing nitrogen solutions: A well prepared table contains all the information that is needed to select the proper solution. In studying this table, the items to observe are:

   (1) Free to total nitrogen ratio
   (2) Salting out temperature
   (3) Vapor pressure
   (4) Water content

   In addition, some calculations plus a knowledge of the plant's equipment and operating conditions will resolve the hygroscopic salt content consideration.

(2) The economics in choosing nitrogen solutions is a matter of calculation using these basic principles. The magnitude of savings that is possible should not be overlooked.

DISCUSSION

If I may for a minute, I want to deviate from this subject. I think the last subject was the discussion of 3-2-2 formulation where preneutralization was mentioned. It has been mentioned several other times. The use of urea containing solutions in a tank is to be avoided. There is a danger aspect involved. A very toxic fume, toxic to humans, we have found will evolve.

I mention this for several reasons. We are quite concerned about it. With the advent of low salting out temperature solutions into which a few per cent of urea has been placed for this purpose, the natural inclination is to take advantage of their properties which fits in preneutralizations in ratios 3-2-2, 2-1-1, or X-O-X.

As far as it is known, this was the first time anyone has attempted to preneutralize urea solutions. The possibility of producing decomposition products from the urea was considered and although no references could be found in the literature, it was suspected that cyanic acid or even hydrogen cyanide could be produced. In our pilot plant experiments the toxic gas was produced and the symptoms experienced by the operators would indicate a cyanogen compound. The symptoms included vertigo, headache, rushing of blood to head, oppression of chest, palpitation of heart, and sensations of constriction of throat. Literature references confirm these symptoms as appropriate to a cyanogen compound.

According to John A. Werner, *The Chemistry of Urea*, "At 100°C. an equilibrium is obtained which is equivalent to 95.5 parts of urea to 4.5 parts ammonium cyanate. The presence of $(NH_4)_2SO_4$ increases the formation of NH_4CNO (ammonium cyanate)."

There are undoubtedly areas of momentary high acidity in the preneutralizer which would liberate HCNO (cyanic acid), a gas at ordinary temperature.

Question No. 10—What Are the Cost Relationships, Tonnage Requirements, and Equipment Needs for Mixes Including Those Containing Minor Elements or Other Additives?

A. Henderson

(1) Addition of minor elements or other additives increases formula cost directly in proportion to the amount of added material for formulas containing filler. For full formulations cost is increased further because more concentrated (generally more expensive) materials are required. In addition, the formula may be changed enough so that conditioners are required.

(2) Other important considerations, some quite indirect, are listed as follows:

   1. Additional material handling.
   2. Additional personnel.
   3. Additional equipment.
   4. Additional storage.
   5. Additional bags.
   6. Tags, labels, etc.
   7. Reduced production rate (overall).
   8. Added clean-up and contamination.

9. More records and inventory.
10. Greater cooperation between sales and manufacturing.
11. Increased analytical work and sampling problems.
12. Special storage and manufacturing precautions.
13. Added management and administrative work.
14. Plant location.
15. Competition.
16. Material purchasing and availability.

(3) No degree of importance can be named for these factors since they will vary considerably with individual plants. For example, a large plant operating at only 50% of capacity would obviously not find storage as important as a smaller plant operating at 80% of capacity.

(4) As long as the tonnage remains only a few percent of total sales its e:ect would not be significant and could be tolerated as so much nuisance business, so familiar to most fertilizer manufacturers. As the tonnage increases it demands varying degrees of attention. In Florida this sort of thing reaches a maximum and most of the tonnage is on a prescription or special basis. Not only are various secondary and trace elements added, but formulas vary greatly with respect to nitrogen types, organic materials, chlorine, etc. It is not uncommon to stock 20/40 different materials and bases for general manufacture and use most of the them in a single busy day. Since this is general practice it is not regarded as a problem, particularly since all manufacturers face the same competitive conditions. Also, the added cost for this type operation is not as great as many believe. This is true because of certain compensating factors, some of which are listed below:

(a) Average production rate is not based entirely on double operation. Grades are made from bases which represent approximately 40% to 80% of the mixture. Bases have been previously manufactured at normal production rates (but are often two component mixtures). In the final step bagging and blending represents one step and straight materials represent a significant amount (approximately 20/60%) of final mixture.

(b) Variety of storage is much greater, but total storage may not be as great. Obviously, variety storage is less efficient because of wasted space. A 400 ton storage space may be tied up with 200 tons of a particular material.

(c) Seasons are more and longer. Shipping may be done by use of two shipping mills, whereas an equal tonnage for a plant in another area may require three to four shipping mills. Other equipment needs may be similarly effected.

(d) Regular use of so-called "special" materials means that they are no longer special.

(5) A true overall cost would be difficult to ascertain, however, a good estimate would be \$0.75 to \$1.50 per ton. This is far less than most people are willing to believe and considering services rendered represents a major contribution to the customer. We perhaps use a great many more grades than are necessary, but considering the total state tonnage, we probably furnish the customer with more of his specific needs than most other areas.

(6) Florida requires more variation than most other states because the variety of crops is greater, soil varies tremendously (have all major soil types), and weather conditions vary significantly. These are some of the reasons why and how special grades develop.

(7) Special or unfamiliar business causes a heavy burden on management and administrative people. Material purchasing and availability may be a serious problem. This involves not only proper contacts and familiarity, but accurate estimation of needs. Since material cost may be 70/80% of total cost, overstocks of special, expensive materials can be disastrous.

(8) Sampling is a real problem. Mixing of 8 to 18 different materials and bases is an obvious problem. Sampling is difficult, both for the manufacturer and regulatory agency. This sort of situation, in addition to placing an obvious burden on the chemical control department, also produces problems for management. Fines are costly — both from a financial point of view and customer relationship.

(9) It is easy to see that certain plants could not produce variety mixtures without having costs sky rocket. If you have a fair estimate of this sort of business it wouldn't be too difficult to calculate your needs and costs. In all probability many plants can produce limited special mixtures without significant increases in costs, and without major expenditures for equipment and personnel. If your plant is so designed and located that it causes major difficulties, the solution is to ignore the business. If the tonnage is great enough that you simply cannot pass it up, then it is large enough to do something about it.

(10) It seems that some manufacturers have put high costs on special mixtures. Some of these may be actual costs, others may be "nuisance cost". I believe that all of us would agree that there are times when somebody should pay for this years "indigestion", and perhaps next season we won't be troubled with it.

DISCUSSION

Chairman Sauchelli: That certainly is an insight into some of those multiple problems that the manufacturer faces in Florida. I am familiar with some of the control problems there, and know of the splendid work they have done in Florida to solve their chemical control problems. They have done a beautiful piece of research work which has helped the fertilizer industry tremendously. The fine cooperative work among the state university, the control officials of the state, and industry is a model for other regions.

A Discussion of the Advantages and Disadvantages of Controlling All Recycle Portions Returned to the Ammoniator-Granulator.

A. Henderson

(1) We assume that "all recycle" means recycle material from two sources: (a) material from air handling system (b) material from screening system.

(2) We can say that "Control" is the key word associated with any good granular system. Further, that it is absolutely essential to control all major factors. Some regard recycle as the most important single factor. Hence the conclusion that it is absolutely necessary to control all recycle. This statement sounds true, but as many know, it isn't. The fact is, that some plants do a good job without means of controlling recycle. If, however, we specify that a good granular system is a near perfect system, then the above statement becomes more significant.

(3) I heard somebody say once that the efficiency of any system is a measure of its means of "staying out of trouble." Perhaps too many of us regard efficiency as a means of "getting" out of trouble, rather than "staying" out of trouble. For lack of a better reason, I believe this concept to be the principal advantage for controlling all recycle. Moreover, if considerable flexibility is required and a very closely sized product is to be made, more controls are necessary.

(4) We cannot speak for all plants and, therefore, we must confine our discussion to a reasonably designed plant. In such a plant the cost of controlling recycle should not be more than $2000, and probably less. All that is required is a hopper, some type feeder, one or several chutes, and perhaps a screw conveyor. The question now resolves to control of "all recycle." First, assume that the principal source of recycle material is that produced by the screening system. We have a fines hopper and a feeder which delivers the material from fines hopper back to the ammoniator at a controlled rate. Now the only material that we have remaining is material from the dust system. This material is more troublesome to handle than regular fines, because it is hot, damp, and naturally has great tendency to cake, bridge, and blind screens. We can introduce this material directly into the ammoniator as it is discharged from the cyclones. This is not controlled; however, since the material is uniform and discharged at a reasonably constant rate it is not a large variable. We can deliver the material from the cyclones to the ammoniator by a screw conveyor. This is partial control and serves to even out the flow. Finally, we can deliver the dust back to the screening system where it is screened, and becomes part of the regular recycle. This, of course, is complete control of all recycle. The problem with this last step is that the hot, damp, dust places greater load on the screens, has tendency to blind screens, and even for short shut-down periods causes caking and bridging in the fines hopper.

(5) It has been our experience that recycle material is not a good means of control except to initially establish equilibrium conditions or to get on formula. Then we make every effort to keep recycle constant. This, of course, is controlling its rate of feed. We believe that it is not a good means of control because of the following reasons:

   (1) Material is variable.
   (2) Reacts to changes slower than H_2SO_4, steam, or H_2O.
   (3) Overloads equipment when used excessively.
   (4) Changes volume relationship in Ammoniator.

(6) In conclusion, we believe that controlling "all recycle" at least to some extent is a most helpful factor. We feel that it is better to partially control material from the dust system by delivering to the Ammoniator by screw conveyor, as against delivering it back to the screen system. Reasons for this have been previously discussed. We feel that as product quality continues to improve, that controlling recycle will become standard practice.

Odor Control Through Odor Counteraction.

Nicholas K. Post

ODOR control is one phase of the large matter of air pollution in general. Air pollution has long been recognized as a public hazard, but odors have not been considered specifically as a hazard: most probably because odors in themselves are not the cause of organic diseases, although the average man believes to the contrary. However, public unwillingness to live with bad smells—general or personal—has been heightened to a large extent by advertising, in recent years, and industrial odors are increasingly being recognized as a very definite part of the overall air pollution picture.

I would like to discuss three aspects of this problem in this paper. First—odor and its relation to the individual and the community; secondly — the theory and principles of odor counteraction; and, thirdly—the application of the odor counteraction method.

The psychological effect of odors as they affect both the individual and the community as a whole are sometimes suprising. Disturbances occasioned by odors that infringe upon health, for example, include low appetite for food, lowered water consumption, impaired respiration, functional nausea, insomnia and mental disturbances.

However, in dealing with physical health we must conclude that malodors are disturbing, but not harmful. Some odors are quite capable of rousing a person from deep sleep and resentment over odor. Broken sleep may perpetuate insomnia long after the odor wave has passed.

Long continued odor exposure, for some persons, drives away all semblance of poise and restraint. This is understandable when we consider odors are credited with providing the shortest route to the subconscious mind. Otherwise calm persons may become mildly hysterical, capable of carrying out acts or making threats entirely foreign to their normal composed selves.

Once the question of a smell or supposed smell has been aired in the neighborhood, a series of developments may occur which verge on the hysterical. Complaints have been registered claiming damage to household contents and garments and assertions made that hair falls out, dogs bark, hens refuse to lay and even that automobiles will not start. In one case an epidemic of measles was claimed in court to be the result of odors coming from a processing plant. Somewhat parallel situations can develop among the workers inside the plant.

The whole problem is further complicated by the fact that odor preference is a specifically subjective matter and our individual likes and dislikes of many odors may depend upon former association of pleasant or unpleasant experiences with these odors. A National Bureau of Standards survey made some years back disclosed that individuals vary in their concept of what specific odor imparts a desirable freshness to the air. In two cases a man chose the odor of herring and a woman chose creosote. It later developed that the man had spent many pleasant days during his childhood in a seacoast area and the odor of herring apparently brought back pleasant memories. He, therefore, considered this odor to be acceptable.

In the case of the woman, her early childhood had been spent at a playground located close to a railroad yard in which wooden ties were creosoted. As in the case of the man, this particular odor brought back many pleasant memories to her and she did not consider the odor of creosote objectionable, but rather as being pleasant.

The human nose is the most sensitive, analytical device known to mankind. Many odors are detected in concentrations of 1 to 10 parts per million. Some of the more noxious odors are perceptible at a dilution of 1 to 10 parts per billion. Again physiological and psychological reactions many times distort the perceptive impression.

A very limited number of scientists have directed their attention to the field of odor perception. Around the turn of the century Hendrick Zwaardemaker, a Flemish scientist, discovered by use of a double olfactometer that two substances odorous singly may be inodorous together.

Many pairs of odorous substances were introduced individually to either nostril to measure the ratio of quantities required for neutralization or counteraction. By this method all possibility of chemical reaction between the two substances was removed.

Various pairs of counteracting odorous substances were discovered by Zwaardemaker in 1895 and some of these counteracting odors were recorded. A modern day parallel is the counteracting ability of the vapor phases of ammonia and ionone. When these two vapor phases are combined neither odor is evident to the layman's nose.

It is important to note that the neutralization or counteraction of odors leaves no overriding odor, pleasant or unpleasant. There is some confusion in both the technical and popular press regarding the terms odor masking and counteraction.

Strong odors tend to mask weaker ones. If two odors are of about equal strength a blend of the two is perceived or possibly both are identified. If one is considered stronger than the other it alone, as a rule, is perceived. This is odor masking.

On the other hand, certain pairs of odors in appropriate relative concentrations are antagonistic and when the two are sniffed together the intensity of each odor is diminished. This is odor counteraction.

The field of odor counteraction, as developed today, is based on the significant work done by Zwaardemaker. The development of odor counteractants has been a pure matter of Edisonian research. Our own laboratory has evaluated some 4,000 odors and odor counteracants and research continues daily.

Industrial odors are complex groups of odors. It is unusual to obtain a specific odor from an industrial process and even when this is done the odor may combine with transient odors in the surrounding atmosphere. For this reason industrial odor counteractant formulations, although designed for specific odor descriptions, may contain complex groups of odor counteractants. There is no widely accepted classification of odors and, as a matter of fact, the description of odors usually depends upon comparison.

The Application of Odor Counteractants

A great number of industrial plants have already installed the best available mechanical equipment to remove particulate substances. In most cases, an odor counteraction treatment is all that is necessary to neutralize the remaining few parts per million of offensive odor and complete the job.

The principle of odor counteraction deals with the molecules of malodor. In the process of odor perception the olfactory tract is so located that ordinarily only gas reaches it. Gas, of course, includes vapor. The sensitive areas of the nose are at the closed ends of channels that are readily penetrated only by diffusion and the diffusion of solid and liquid particles of more than submicroscopic size is almost neglible. Accordingly, characteristic odors are rarely, if ever, produced by a smoke or mist, however fine, of solid or liquid particles, except of material volatile enough to be smelled when only the vapor comes from massive forms of them.

For practical purposes an odor is always a gas molecularly dispersed in the air in sufficient concentration to be above the threshold level of perception. For this precise reason odor counteractants are most effective when vaporized and combined with the air stream by molecular dispersion. Regardless of whether the stream of exhaust is held to the ground by air inversion, is vertically dispersed, or horizontally dispersed, the counteractant is carried with the malodor and is noticeably effective until the odor is dispersed beyond the range of perceptibility.

Odor counteractants are vaporized by atomizing the counteractant into the air stream by means of a calibrated atomizing nozzle. These vaporizing points are usually located at the ground level. At the plant roof top and at the stack tip in the vicinity of most odorous effluents. This provides vertical coverage from the bottom to the top of the odorous pool.

The odor counteractants mix with the odorous air stream by molecular dispersion and air movements are designed to follow the physical behavior pattern of the odorous elements. Some odorous elements disperse beyond the limits of perceptibility rapidly. Others are tenacious and do not disperse horizontally or vertically as quickly.

Public opinion is a factor in air pollution control. Lack of a public relations attitude toward the problem of air pollution is a serious matter. The fertilizer industry's relations with the general public are extremely important. An aroused public is an unreasonable public. An unreasonable public can cause excessive expenditures.

It is, therefore, essential that industry survey its position to determine the most advantageous course of action in reference to odor pollution control.

Question No. 11—Is it Possible to Successfully Eliminate Objectional Fumes From the Continuous Ammoniator's Exhaust, and Are There Any Known Methods of Eliminating Ammonium Chloride, Ammonium Nitrate and Ammonium Sulfate Aerosols from the Exhaust Fumes from Dryer and Ammoniator?

W. G. Mautner

THE best way to eliminate objectionable fumes from the continuous ammoniator exhaust gases is to do everything necessary to prevent their formation in the first place. Minimum evolution of ammonium chloride, sulfate and nitrate aerosols during ammoniation can be obtained by

1. Keeping sulfuric acid used for heat or reacting with the excess ammonia to a minimum.
2. Substitute solid ammonium sulfate for that made in the ammoniator by sulfuric acid and anhydrous ammonia as it is usually cheaper per unit of nitrogen than that made in the ammoniator. This is especially true in 1-1-1 ratio grades.
3. Use phosphoric acid to replace sulfuric acid in high analysis grades. The reaction between H_3PO_4 and KCl is much slower than that between H_2SO_4 and KCl, hence less HCl is formed in the ammoniator to combine with the ammonia vapors.
4. Proper ammoniator bed conditions. Over agglomeration, variable feed conditions, excessive temperatures all contribute to the formation of smoke.
5. Keep reaction temperatures in the ammoniator within reasonable limits. Generally, if the heat developed in the ammoniator is such that the temperature of the granulated fertilizer discharged from the ammoniator exceeds 225°F, there will be excessive smoke formation.
6. The use of steam to replace all or part of the sulfuric acid, especially in fertilizer containing less than 5% nitrogen.
7. Check worn or corroded sparger pipes and replace promptly. Poor distribution of sulfuric acid and nitrogen solution often causes serious fuming. Spargers should be inspected daily for corrosion and erosion of sparger holes.

The fumes evolved from the ammoniator and dryer exhaust gases, other than dust particles, are true smokes of a particle size in the range of cigarette smoke. Most dust collecting apparatus will not remove the ammonium chloride smoke. Experimental work conducted by our company indicates that a high pressure drop orifice scrubber followed by a spray will eliminate 90% to 95% of the smoke. A pressure drop of 30 to 35 inches of water across the orifice is necessary. A fan of some 150 HP would be necessary to process 30,000 cu. ft./min of air.

Question No. 12 — Is There Any Experimental Information Available Where Phosphoric Acid is Sprayed on Top of the Bed?

T. E. Martin

SEVERAL users of phosphoric acid are spraying or dribbling it on top of the rolling bed in a TVA ammoniator. Of course, the advantage gained by introducing the acid this way is that one sparger pipe less is required in the bed, and the fewer such pipes the less the interference with proper rolling and lifting action.

There are a number of possible disadvantages to top feed of the phosphoric acid in addition to possible greater fume evolution as discussed by Mr. Nielssen. One is the possibility of splashing, creating an accident hazard or corrosion hazard. This can be eliminated by applying the acid close to the bed, and under only enough pressure for adequate distribution.

A second possible disadvantage is this: Acid applied on top of the bed rolls down to the bottom of the bed quickly, and is then carried up the shell. Reaction of the acid with ammonia tends to be delayed and the average temperature and liquid phase percentage are somewhat different. Increased shell corrosion might be expected, but practically this does not seem to be serious. Additional time is required to fully answer the corrosion question. Another and more serious consequence of the roll-down and carry-up of the acid along the shell of the mixer occurs when large quantities of acid are used per ton of mixed goods. In such a case this method of application offers the greatest chance for sufficient wetting of the shell so that sliding of the bed occurs instead of carry-up such as is necessary for mixer operation.

As we know, it is important to the action of a TVA mixer that the liquid phase should be discontinuous. As soon as the surface tension of the liquids present forms a sheet of liquid, so that the gaseous phase is no longer continuous, the mixer operation is in trouble. I have been concerned about the possibility that this is more likely to occur with top feed of the acid than with subsurface feed. So far I have been unable to confirm this fear from experimental evidence.

The eventual distribution of the phosphoric acid or its reaction products throughout the mixed goods product seems to be about the same for top application of acid as for subsurface introduction of this material.

Question: What is the maximum practical ammoniation rate using anhydrous ammonia and the several phosphate materials?

Answer: The following ammoniation rates are practical and are widely used:

Triple — 4#/unit APA
20% Super — 6#/unit APA
Phosphoric acid — 7#/unit APA

These are not maximum rates, in that these rates can usually be attained without appreciable loss of ammonia, provided the ammonia is fed subsurface in suitable mixing equipment. They may be regarded as maximum practical rates, at least at present. The rate for phosphoric acid can be run up to 7½#/unit APA with reasonably careful operation without appreciable ammonia loss.

Of course, the attainment of maximum ammoniation rate is a kinetic problem, and it is known that much higher rates than the above can be attained if sufficient time for attainment of equilibrium is allowed. Practically there is a definite limit on the reaction time (or mixer holdup tonnage) allowable. The design, state of maintenance, and operation of the mixing equipment have a very important effect on the reaction kinetics. The physical condition (porosity, state of fineness, moisture content) of the solid phosphatic materials is of great importance. It is well known that higher temperatures increase reaction rates and therefore the amount of ammonia absorbed.

It is believed that the maximum practical ammoniation rates will gradually be increased as materials, equipment, and operation are improved.

F. T. Nielsson

IN 1952 at TVA, I investigated the effect of acid addition during continuous ammoniation to tie-up more ammonia than could be absorbed by superphosphate alone. In those tests a supermuriate mixture was being ammoniated with anhydrous ammonia. Initially, phosphoric, nitric, and sulfuric acid were sprayed on the bed. This was the first time that we had tried the use of acids.

Phosphoric acid caused a fair amount of white fume to be evolved. Sulfuric acid caused dense white fume evolution. The use of nitric acid resulted in brown fume evolution, and no nitrate nitrogen was found in the product.

A subsequent test with sulfuric acid being added under the bed indicated that fume evolution would be minimized. At that time no further work was tried with phosphoric and nitric acids.

It is well known that phosphoric acid added under the bed almost completely eliminates the fume associated with the use of sulfuric acid. Only a plant trial will determine how satisfactory the spraying of phosphoric acid on top of the bed would be.

It may cost you only a couple of dollars to put a pipe through and get a hole and spray it. I don't think a plant trial would involve too much work.

DISCUSSION

Mr. T. E. Martin: Frank Nielsson has been short about this, and I am sure we all appreciate that at this time. So let me say just a few words in a few minutes.

Several users of phosphoric acid are at present spraying or dribbling the acid on top of the bed of the TVA ammoniator. Of course, the advantage to be gained by introducing the acid this way is that one sparger pipe less is required in the bed. Some people are getting an awful mess of piping underneath the bed, which interferes with the carrying up and rolling down of the bed in a manner which is necessary to proper operation.

There are a number of possible disadvantages in addition to the fume problem which Mr. Nielsson mentioned. One is the foolish one of possible splashing of acid, causing a personnel hazard or a corrosion hazard. This can be minimized if you keep the pipe spraying the acid low enough.

The second possible disadvantage is that acid applied on top of the bed with the TVA ammoniator rolls down along with the dry fertilizer to the shell, and then is carried up along the shell, largely before it is ammoniated. Possibly on the second pass-through is when it is ammoniated, to a large extent at least.

The reaction tends to be delayed then with ammonia. The average temperature in liquid phase percentage can be different from what you are used to if the acid is sprayed under the bed. Increased shell corrosion might be expected. Apparently, from what I have seen, there actually isn't any increase in shell corrosion, but time will tell.

Another and more serious consequence of this rolldown of the acid wetted fertilizer being carried up along the shell is that if we are putting in large quantities of acid, as in some of these high analysis grades these days, the fertilizer in contact with the shell may be wet enough to be muddy and, instead of carrying up and rolling down, it may start sliding, and of course the TVA ammoniator does not work under these conditions.

As we know, it is important to the reaction of the TVA ammoniator that the liquid phase should be discontinuous, that the solid particles wetted with liquid should not, by the surface tension of the liquid, sheet over and form a liquid sheet. If this happens with the gaseous phase, no longer a continuous phase, the mixer operation is in trouble.

I had thought that putting the acid on top of the fertilizer bed might tend to cause this condition. Again, apparently, in actual plant trial it doesn't cause it any more than putting the acid under the bed.

The eventual distribution of the phosphoric acid through the mixture or the reaction products of phosphoric acid to the mixture seems to be about the same when it is put on top as when you put it under the bed.

Question No. 13—How Can a No or Low Nitrogen Grade Be Formulated Economically to Produce a High Quality Granular Product with a Maximum Recovery and Minimum Recycle?

H. P. Bailey

No Nitrogen Grades

ONE of the most popular formulations to produce a no Nitrogen granulated fertilizer was given to me as follows.

To regular Super, and/or Triple, and Potash, add enough powdered Calcined Dolomitic Lime, chemically known as Magnesium Calcium Oxides, to neutralize a large part of the free acid. To neutralize the acid, some operators formulate by adding 1 lb of Oxides per unit of P_2O_5. Others add 40 lbs to a 0-25-25 analysis, 35 lbs to 0-20-20, 30 lbs to 0-14-14, etc. To the mixture of Super, Triple, Potash and Oxides, 12% to 14% hot water is added, then granulate and dry with an exhaust temperature from 250°F to 330°F to produce a fertilizer having up to 5% free water.

The higher drying temperature is preferred as it tends to increase productivity. The lower temperature is, of course a must, when using the bag dust collecting system.

To obtain productivity and quality of product in the no Nitrogen grades, probably the most important operation is to neutralize a large part of the free acid. Acids are trouble makers. They have a tremendous affinity for water. Acids plus water tend to make a gummy, sticky fertilizer that may lead to bagging problems, bag rot and caking.

Some operators maintain production controls to be sure the finished fertilizer has a low acidity. When this is done, they can produce a quality product having up to 5% free water at a high productivity.

Other operators doing little or nothing about controlling acidity have found that it is necessary to aim for 1% free water to obtain a quality product. Since more free water is therefore removed, an extra load is put on the dryer and productivity is off considerably.

According to information given me, production was increased up to 100% when the free water tested 5% and the free acid less than ½% as compared with 1% water and over 2% acid.

Low Nitrogen Granulated Grades

There are probably four important operations to produce the low Nitrogen granulated grades.

No. 1 Ammoniation temperature should be 220°F or higher.
No. 2 Reduce heat radiation.
No. 3 Control the acidity of the finished fertilizer.
No. 4 Reduce the free water to less than 3%.

Let us discuss each one of these.

Referring to Operation No. 1—Ammoniation Temperature. To produce the hard, strong granule, I find the operators agree almost 100% that it is necessary to ammoniate at 220°F or higher. If a lower temperature is employed, there is a tendency to produce the soft, weak granule that may bag cake. Chemical heat has been found to be very satisfactory to develop the 220° minimum temperature. The following simple method may be used to estimate the ammoniation temperature.

For each pound of anhydrous

ammonia neutralized, add 1.7°F per ton of fertilizer. Therefore, if you formulate with 100 lbs of NH_3, a temperature of about 170° is developed. Adding the raw material pile temperature which is assumed to be 68°, we have a total temperature of 238°F. This temperature is well above the minimum 220° and should enable you to produce the hard, strong granule.

Now let us take another example. Suppose the formulation calls for only 75 lbs of NH_3, or, putting it another way, suppose there are good reasons for only formulating with 75 lbs of NH_3 and you choose to obtain any additional nitrogen from another source. This 75 lbs of NH_3, multiplied by the factor 1.7 develops a temperature of about 128°F. adding the 68° pile temperature, we have a total of 196°, or 24° less than the recommended minium temperature.

To develop the additional 24°, operators have found the Powdered Magnesium Calcium Oxides to be the best and most economical alkali. This material, when neutralized, develops a temperature rise of about 1.2°F per lb per ton of fertilizer. Therefore, the addition of 20 lbs of Oxides develops about 24° plus the 196° to make a total of 220°, thereby meeting the recommended miniumum temperature.

Referring to Operation No. 2—reduce heat radiation. As explained before, 100 lbs of NH_3 should develop an ammoniation temperature of about 238°, however, many plants only develop about 180° or so. On the other hand, plants ammoniating with the 70 lbs of NH_3 plus 20 lbs of Oxides often develop a temperature as high as 250° instead of 220° as estimated before. Why the difference? Here's a possible explanation. Some operators wind sweep their process thereby removing considerable chemical heat. Wind sweeping may have its place in certain high analysis formulations where it is no problem to develop high temperatures and where it is necessary to control the chemical heat. However, in the low nitrogen grades where it is usually a problem to develop enough chemical heat, wind sweeping is not recommended. A few operators have realized this and omitted the operation, in fact, some are now employing a closed granulating process operating under 10 lbs or more pressure by the use of flapper valves. This tends to conserve the chemical heat and causes an additional temperature rise.

Referring to Operation No. 3—Control of Acidity. This is also recommended in the low nitrogen grades as well as in the no nitrogen. Again, the addition of powdered Magnesium Calcium Oxides is recommended to reduce the acidity and for a simple plant control test where comparative results are acceptable, the use of Methyl Orange is satisfactory providing the color test indicates the pH is above 4.3. This indicator has a pH range from about 3.3 to 4.3 Fertilizer may be tested by spotting the indicator directly upon the surface of the sample and noting the color change. Fertilizer testing about 5 pH should be all right, below this you may experience difficulties.

Referring to Operation No. 4—Reduce the Free Water to Less than 3%. The removal of water *halts* chemical reactions and crystalization, and in turn prevents bag caking. It follows that a low free water content is preferred as it offers some insurance towards the production of a quality product. On the other hand, the removal of water is an item of expense and will tend to influence productivity. A large number of operators say they are well satisfied with less than 3% free water providing they ammoniate at 220°F or higher and police the acidity as discussed before.

Productivity

To formulate a low Nitrogen analysis, some operators believe raw material cost is the "yardstick." And there are others who prefer to use more chemicals and in this way increase productivity. The latter will show a higher raw material formulating cost but a lower overall cost which is what counts.

For example. Many operators formulate with extra Sulphuric Acid and Powdered Magnesium Calcium Oxides. The acid replaces part of the water as the liquid phase and therefore less water is to be driven off. This puts a smaller load on the dryer, also less recycle is reported thereby increasing productivity. As for the Oxides, they neutralize some of the acid, raise the temperature to speed up the chemical reactivity and also form hydrated salts, again putting a smaller load on the dryer. Possibly 20 lbs of Oxides will combine with as much as 30 lbs of free water.

In a 4-16-16 analysis, some operators add up to 220 lbs of 60° Sulphuric Acid.

In a 5-20-20, up to 300 lbs have been added.

Plants using the high Acid-Oxides have reportedly increased their production up to 400%.

I am grateful to some 600 operators, technical and research men from Florida to Canada who have assisted me in preparing this paper and would like to take this opportunity to acknowledge and thank them very much.

Question No. 16—Economics of Phosphoric Acid In Granulation.

Chairman Sauchelli: We shall go to Question No. 16, "A discussion of the economics of phosphoric acid in fertilizer formulations," which is something of increasing importance, something new.

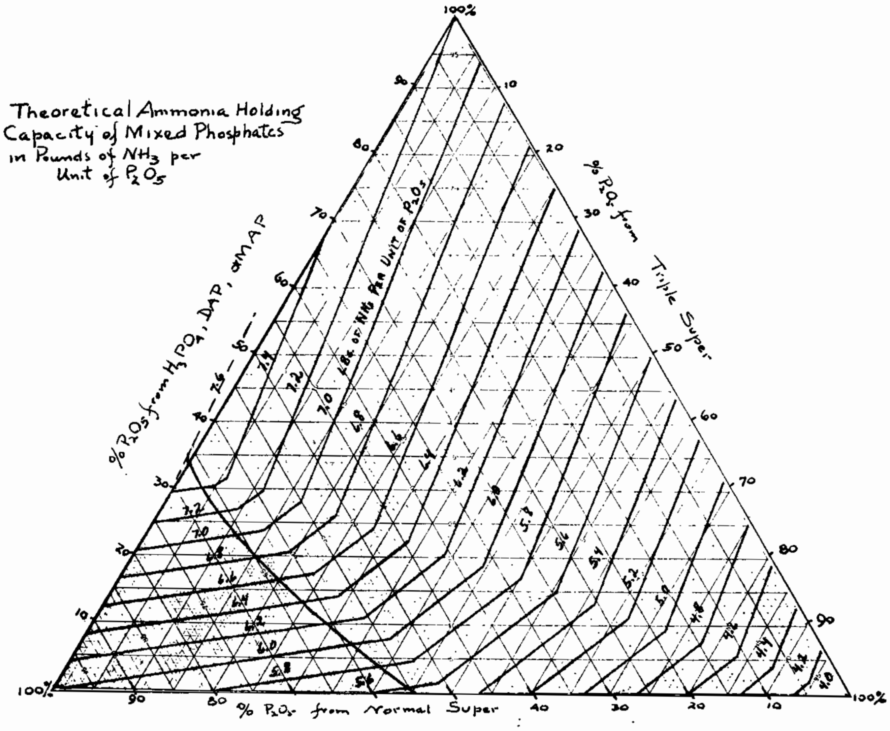
We have Carl Schumaker to discuss this question.

C. P. Schumacher

I WOULD like to start by saying that I believe the key to the economics or the economic use of phosphoric acid is its synergistic effect with normal superphosphate. Phosphoric acid has a synergistic effect with normal superphosphate. There is a gypsum action which does permit phosphoric acid to be ammoniated at higher than normal rates in the presence of normal superphosphate. When the units of P_2O_5 from phosphoric acid are one-half or less than the units of P_2O_5 from normal superphosphate, we find that this amount of phosphoric acid can be ammoniated at rates as high as 10.8 pounds of ammonia per unit of P_2O_5. This we believe is the key and does promote higher ammoniation rates in phosphoric acid and superphosphate combinations.

The triangular diagram which our people have worked out was mentioned earlier, and I do have a slide of it here if we could have it projected, please.

(Slide) This represents 100 per cent triple superphosphate, with zero triple superphosphate being the side of the triangle away from me. One hundred per cent normal superphosphate is the lower left-hand corner, with zero normal superphosphate being the side of the triangle nearer me. The base of the triangle is zero phosphoric acid for zero P_2O_5 from either phosphoric acid, diammonium phosphate or monoammonium phosphate sources, with the upper vertex of the triangle being 100 per cent P_2O_5 from these sources.



There are lines on this diagram indicating ammoniation rates at any position within the triangular diagram. You see up here 100 per cent P_2O_5 from phosphoric acid, diammonium phosphate, or monoammonium phosphate. We find that P_2O_5 can be ammoniated at a rate, if you follow this line up, of 7.2 pounds ammonia per unit of P_2O_5.

In order to draw a chart such as this, we have to consider specific values for ammoniation rates, and we have chosen a specific value for triple of 4 pounds of ammonia per unit of P_2O_5 and 6 pounds of ammonia on normal superphosphate.

The actual ammoniation rates that you would find in normal production may vary from this and can be taken into account when using this chart by selecting the point on the chart and determining the ammoniation rate. If you find that the rates in actual practice are lower than the ones we have used here, by a percentage factor you can reduce the expected ammoniation rate.

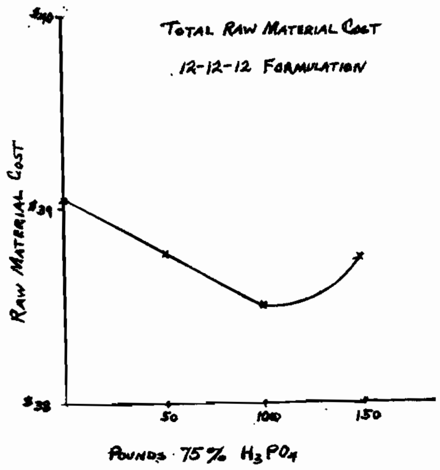
The way this chart is used is to determine in any given formulation the total per cent of P_2O_5 requirements obtained from each of the three P_2O_5 sources. The point right in the middle, for instance, would be 33 per cent P_2O_5 from normal, 33 per cent from triple, and 33 per cent from phosphoric acid. A point down at the bottom half-way in between normal and triple would have zero phosphoric acid in it. A point at this side of the chart would have zero normal superphosphate.

I have drawn another line on this triangular diagram, which is this curved line coming up on the left-hand corner there. These are P_2O_5 compositions which we have found produce workable 12-12-12 formulations. At the bottom of the line we are making a 12-12-12 with no phosphoric acid. If we increase phosphoric acid in the formulation to the point where it replaces all of the triple superphosphate, which puts it on this side of the diagram, we see that our ammoniation rate is increased from theoretical 5.6 up to 7.6.

This we believe is the key to the economic use of phosphoric acid. You improve your ammoniation rate and, in improving the ammoniation rate, you can potentially use more solution, you can potentially use less sulfate, you can potentially eliminate the use of sulfuric acid which contributes nothing but cost to the formulation. It contributes no nutrients.

In actual practice, which is where I am afraid we will have to move the table back again, for the same 12-12-12 formulations I have plotted cost against phosphoric acid content. We find when we look at that chart that as you plot cost of formulation against phosphoric acid content, there is frequently a minimum. Formulations are plotted on this curve at a constant calculated recycle using moisture and heat considerations.

On the bottom we have



pounds of 75 per cent phosphoric acid in the formulation. On the side we have the raw materials cost of that formulation. This is done for a constant recycle consideration. You find the minimum cost for this formulation at approximately 100 pounds of 75 per cent phosphoric acid.

Why is there a minimum? If phosphoric acid is so good, why not replace all of the triple superphosphate?

As Mr. Hignett pointed out, phosphoric acid does contribute moisture to the formulation, and you have to do something about this moisture consideration. That requires the addition of more dry material. In this particular series of formulations the cost has been decreasing as we increased the amount of phosphoric acid up to 100 pounds, because we are using less sulfuric acid. I have the exact formulations here, and I note as we increase phosphoric acid we are increasing the amount of ammonium sulfate each time in very small increments in order to keep the formulation at a certain dryness, that is, to keep the liquid phase at a certain maximum. When we go beyond 100 pounds of phosphoric acid we lose control of the thing, and we are adding so much moisture we have to add excessive amounts of ammonium sulfate.

This is where the economics of phosphoric acid can backfire on you. I should point out that this is true of this 12-12-12 run which was made. It is not necessarily true of all 12-12-12 runs or all other 1-1-1 runs. It is all a function of raw material costs which is a factor depending on where your plant is located and what raw materials are available.

The raw material costs used in this example are $1 per unit for normal superphosphate, $1.33 per unit for triple superphosphate, $1.49 a unit for phosphoric acid, 60 cents a unit for potash, $21.20 a ton for sulfuric acid, and $1.35 a unit for the nitrogen solution used. This is a high fixed-to-free ratio nitrogen solution, Solution 410, having ammonia 19 per cent and ammonium nitrate 72.5 per cent.

When we find in some cases the liquid phase is increasing and the use of phosphoric acid has gotten out of hand, there are certain advantages to using dry forms of P_2O_5 which have similar ammoniation characteristics to phosphoric acid. These dry forms can be diammonium phosphate or monoammonium phosphate. Although here once again the economics may be a problem, these materials could possibly be considered as giving good economic formulations depending upon your geographical location.

Chairman Sauchelli: Thank you, Carl.

Any questions to ask Mr. Schumaker?

Mr. D. DeLapp: My name is DeLapp, American Cyanamid Company. I would like to know if the curve which was presented last reflected a 25 per cent water content phosphoric acid or an 18 per cent water content phosphoric acid.

Mr. Schumaker: That was 75 per cent acid containing 25 per cent water.

Mr. DeLapp: Would a curve with wet process acid that contains less water continue the poundage of phosphoric acid out to a lower amount and affect the total cost of the formulation? Have you made a similar calculation?

Mr. Schumaker: I have not, but it would be of interest and I think you might be right. You would not be fighting the water problem as much.

Packaging Survey

W. F. Jacobi

The studies which we have made are also made by any of the major suppliers for the larger companies. It is a service which most of them perform. Actually it is industrial engineering, a study of materials handling, the problems involved, what it means to you in dollars and cents.

We have with us this afternoon a very distinguished panel of bag people down here: Stewart Eckers of Bemis Bro. Bag Co., Travis P. G. Barham of St. Regis Paper Co., and Ed Pyle of Raymond Bag Co.

Over the past year and a half we have made a lot of plant surveys. By "plant surveys" I mean time studies. We have set up standards for handling bags—for instance, a hand truck, pallet loads, conveyors, that type of thing. We have tried to level it geographically in different parts of the country, union and non-union plants, the time involved, different types of personnel.

We set up these standards and tables on the basis that you should know whether or not you have competent personnel. In other words, it is generally a matter of opinion. Someone says, "Boy, I have the best bag hanger in the business. He can hang bags faster than anybody that you know of." Of course, he might put half of them on the floor, but he can handle bags faster than anybody else. Or you will hear someone say, "I have the best sewer in the business. He can sew faster than anybody else." But generally we have found that is a matter of opinion. No standards have been established as to what you should get per-hour per-man. It is usually a matter of guesswork or a matter of how the superintendent of the plant or the bagging foreman feels about it.

So we endeavor to go into these various plants and study them right from the outset, their present methods of operation, the standard times involved in doing that, what it costs them per ton to do that, and then sit down and analyze and figure how this can be leveled. out.

Actually, we came up with a total savings average on these plants of 48 cents per ton, which is not hay in these days of price-cutting, unstabilized products, and so forth.

These charts which I shall show you are projected on the basis of 16 companies. These 16 companies were picked geographically. In other words, we took companies in the Midwest, the Southeast, and the Northeast. We took not so many in the Northeast, for there are not too many up there. The Southeast differs so much from the

Midwest in its methods of handling and packing that we had to balance these.

So we took 16 companies. These 16 companies had 34 plants. The 34 plants were surveyed. We made time studies, as I explained before. We made cost analyses. We analyzed their present operations, projected what could be done, and then waited until it was done in order to set this up. In other words, this is not theory. What I want to show you now is factual. It has been done. We could give you the names of the companies. We don't intend to, because I don't think you would want me to give your confidential figures, and I know the other people wouldn't want me to. Actually, I can assure you at any time we could substantiate this.

I want to make another thing clear before we even start, that this can be done by yourselves if you want to spend your own money. This sort of thing can be done by your suppliers, is being done by your suppliers, and if I were you I would take advantage of it, because surely if I were in business for myself I would get everything I could get for nothing, believe me. So these services are available.

We broke these down into two categories: One is your present method of handling, your present method of materials packing. There is an error on these charts which I will show you. We are talking about product savings. When we talk about product savings we are talking about the savings that can be made in weight, handling, and other things. In other words, if a man dumps 50 pounds on the floor you are not going to get 50 pounds back when you pick it up. I believe it was Al Spillman who said the other day you sneak it back into the elevator. You dump 50 pounds, gentlemen, and you are going to get only 35 pounds back in that elevator, believe me, because most of the floors have big cracks in them and that is where it goes. All this includes materials savings or product saving as far as your weights are concerned, as far as waste is concerned, and as far as good housekeeping is concerned.

The other point which it includes, which, as I said before, any of these big bag companies can do, is redesign. By that I mean not only construction. The average bag salesman comes in and says, "I can save you $10 basis weight," which means $1.50 per thousand. The fact that it breaks all over the lot and it costs you $2 a thousand to replace them is overlooked. The point is, it includes not only basis weight and construction but redesign as far as the type of paper that you are using.

Somebody's great grandfather may have founded the firm and he used a yellow sheet of paper which he thought was beautiful and which was cheap at that time and he persists in using it. When you analyze it, that yellow paper may be costing you two or three cents a fertilizer ton when it isn't even necessary. Or it could be brown or green, or whatever it is. Good redesign as far as the art work is concerned is not just for the aesthetic values but it actually can amount to dollars and cents as to what you can save on redesigning your art work to fit into a family package an dstill at the same time enable you to take advantage of cheaper materials.

I think that is the thing that is most important to all of us in this penny business, where your profits amount to pennies, where you must save it. That was one phase.

The other phase was the study of the bagging operations. I shall not go into what types of bagging operations. I think you have all been belabored with the various people who are selling open-mouth packers, valve packers, and so forth. I am sure all of you are well acquainted with that story, so I shall not go into that, but there is money to be saved all the way along the line.

Should you use hand trucks? Should you use conveyors? Should you use pallets? Each one of those presents a problem. There is no over-all answer to that. A plant which has lots of room can use pallets, but a plant which is limited in its space cannot use pallets. Remember that a lift truck has to turn around. It has to maneuver. What are you going to do with this aisle space? Or maybe it is conveyors. It seems wonderful that you just put stuff off the end of the packer and it goes on a conveyor right out to the truck or the car. That is fine if the truck or car can get to the same place each time. But when you have five or six

Summary of Annual Savings

	Available by Conversion to Recommended Equip. & Bag Types on all Paper Bags	Available by Conversion to Recommended Equip. 200 Pound Bags	Available by Material Give-away Reduction	Available by Improved Material Hdlg.	Combined Total Savings
Atlanta	$ 9,507.75	$4,050.00	$3,150.00	—	$16,707.75
Charlotte	13,519.39	2,093.60	1,952.20	$15,413.60	32,978.79
Knoxville	4,246,75	1,128.00	1,200.00	—	6,574.75
	$27,373.89	$7,271.60	$6,302.20	$15,413.60	$56,261.29

OTHER ADVANTAGES

1. Higher equipment operating efficiency.
2. Reduced overtime labor costs.
3. Lower bag breakage.
4. Added sales appeal
5. Easier handling.
6. Improved customer service.

trucks lined up and two or three cars, you can't get them to the same place. So our studies indicate that the good old hand truck is not to be overlooked. A hand truck which can go eight high and load them into a truck eight high is not to be overlooked.

Atlantic Plant

75M Tons—Annual Capacity
40% Paper—100 Pounds
60% Burlap—200 Pounds

Type	Analysis Grade	Bag Type	Bag Size	Approx. Percentage Total Tonnage	Approx. Tons Bagged In Paper
Pelletized	5-10-10	SOM	18½x4x33	1½	450
	8-0-24	SOM	18½x4x33	3	900
	10-10-10	SOM	18½x4x33	5½	1650
Pulverizer	20% Super	SV	18½x5x34	½	150
Pulverizer	Other	SV	18½x5x32	89½	26,850
			TOTAL:	100	30,000

Tonnage in Paper — (40% x 75,000) — 30,000 tons
Tonnage in Burlap — (60% x 75,000) — 45,000 tons
TOTAL: 75,000 tons

Charlotte Plant

60M Tons — Annual Capacity
60% Paper—50 and 100 pound capacity
40% Burlap—200 pound capacity

Capacity	Type	Analysis Grade	Bag Type	Bag Size	Approx. % Total Tonnage	Approximate tons Bagged in Paper
100	Pulv.	20% Super	SV	18½x5x34	3	1,080
	Pulv.	0-14-14	SV	18½x5x34	4	1,440
	Pulv.	4-12-12	SV	18½x5x34	3½	1,260
100	Pell.	6-8-6	SOM	18½x4x33	1	360
	Pell.	8-0-24	"	"	½	180
	Pell.	8-8-8	"	"	2	720
	Pell.	10-10-10	"	"	3	1,080
	Pell.	14-0-14	"	"	1	360
100	Pulv.	Other	SV	18½x5x32	67½	24,300
50	Pell.	5-10-10	SOM	13½x4x26	2	720
	Pell.	10-10-10	"	"	3	1,080
	Pell.	14-0-14	"	"	½	180
50	Pulv.	2-12-12	SV	13½x4x29	8	2,880
	Pulv.	6-8-6	"	"	1	360
				TOTAL:	100	36,000

Tonnage in Paper (60% of 60,000) 36,000
Tonnage in Burlap (40% of 60,000) 24,000
TOTAL: 60,000

Knoxville Plant

50M Tons—Annual Capacity
20% Paper—100 Pounds
80% Burlap—200 Pounds

Type	Analysis Grade	Bag Type	Bag Size	Approximate Percentage Total Tonnage	Approximate Tons Bagged in Paper
Pulv.	20% Super	SV	18½x5x34	½	50
Pulv.	Other	SV	18½x5x32	99½	9,950
			TOTAL:	100	10,000

Tonnage in Paper (20% — 50,000) 10,000
Tonnage in Burlap (20% — 50,000) 40,000
TOTAL: 50,000

Our studies indicate that 25 per cent of the time in trucking is spent in waiting. In other words, when you have hand trucks moving back and forth, 25 per cent of the time is spent waiting while one truck is being loaded before the next one can be moved in. The solution to that is very simple.

The same way with pallets. I have gone into plant after plant where the pallet is set in front of the off-loading conveyor and people are waiting while they load this pallet. The lift truck takes it away, the next pallet is not there, and everyone stands around and waits. There is no reason why you can't line up three or four pallets on a roller conveyor and move them under so the lift truck will take the pallet on the end. This is costing you dollars and cents. You would be amazed the amount of money that it does cost you.

I shall show you a few charts because I know I am limited on time, and I shall take advantage of getting out of here easily by throwing these charts on. I want to show you some time studies which were made on hand trucks, on pallets, and on conveyors. I shall not put them on there long enough for you to study them, for two reasons. One, we are limited in time and, two, you might ask me a question I couldn't answer, and I don't want to be embarrassed.

Method of Conducting Survey

To obtain and analyze the necessary data for this survey and to recommend more efficient equipment and methods to effect realistic savings of $56,261.29, the procedure used was to:

1. Visit the Atlantic, Charlotte, and Knoxville plants to obtain and record data on present:
    - a) Analysis of paper sacks including:
        - 1) Type bag used
        - 2) Weight of filled bags
        - 3) Filled height
        - 4) Stacking dimensions
        - 5) General appearance
    - b) Bag types, sizes, construction, printing, special features and costs.
    - c) Packing equipment, methods, rates and personnel.

d) Material handling equipment, rates, methods and personnel.

2. Analyze the above data and recommend more efficient methods and equipment to effect savings. This required a detailed breakdown of both present and proposed labor and material cost.
3. Substantiate the revised bag sizes by conducting bag filling trials, checking:
   a) Bag dimensions and specifications
   b) Filled weight and height
   c) Stacking and pallet dimensions
   d) General appearance

During filling trials particular ttention was paid to the less dense, ulverized grades (20% superphos- hate, 0-14-14, and 4-12-12) and all elletized grades. Due to certain nalyses not being packed under egular production conditions, all rands were not checked in this anner. However, where possible, ontents of filled bags in storage ere substituted.

Recommendations for All Plants

. Convert all sewn valve bags to sewn open mouth style including the Sew Strong reinforcing tapes.

. Convert bag filling equipment at all plants to automatic high speed I&C open mouth filling scales.

. Adopt the use of wooden pallets and fork trucks at Charlotte.

The total equipment cost of dopting this program would mount to $28,682.80 and would esult in a saving of $56,261.29. he payoff period, therefore, is .58 years, or slightly more than one-half year.

DISCUSSION

Monitor Marshall: Has anybody any questions? We have a few minutes for a very few questions.

Mr. W. B. Bird (Summer Fertilizer Co., Baltimore): What are the advantages and disadvantages between gusset bags and tubular bags?

Mr. Jacobi: Flat bags. Do you want to answer that, Stewart?

Mr. Stewart Eckers (Bemis Bro. Bag Co.): The advantage in the gusset bag would be, No. 1, that it would give you a better package, a better looking package; and, No. 2, the bag itself is stronger because it is handled by the ends and the gusset reinforces it for handling. However, a lot of flat tube bags are being used. If you want to make a real, honest-to-goodness comparison, you will use less paper in the flat tube bag than you will in your gusset bag.

Does that answer it?

Mr. Bird: Yes.

Mr. Jacobi: On a flag bag or flat tube, if you were using a 15 by 4, let's say, or 15 by 15 gusset bag, you would have 20 inches where you have 25 inches across the base. If you should convert that to a flat tube, you would then have a 20-inch base, which would increase the cost of your sewing materials 25 per cent or thereabouts. So if you figure that the average cost per thousand bags is about $1.25 or $1.30 for closing materials, if you take the gusset out of it, gentlemen, you will increase that anything from 20 to 25 per cent on your materials costs.

Final Comments by Chairman

I want to say something about e attendance at this meeting. Dr. arshall gave me a very nice break- own by states, and it is an interest- g thing. You ought to know omething about it.

Apparently we have here to- ay at least 274 people from the rea east of the Mississippi and orth of the line Arkansas-Tennes- e-North Carolina, the Northeast.

In the Southeast, that is, from ates east of Texas, Louisiana, and Arkansas as the western line, and then the boundary Tennessee and North Carolina, 43 people.

The Southwest and the Pacific, 19 people. Five from California this year. Three from Utah. One from New Mexico. Four from the great State of Texas. Six from Oklahoma. Three from Kansas. Two from Nebraska.

That is an interesting showing. It indicates, I think, a number of things to us: the intense interest in granulation and ammoniation. The Southeast apparently has problems which are a little different from the Middle West and the Northeast, because they do not do so much granulation and ammoniation there. Maybe that is one reason that next year we should concentrate on some of the problems of the Southeast with the nongranulated fertilizers, and induce more people from that region to attend our Round Table because we will be dealing specifically with problems which are peculiar to their region.

We have seven visitors from Canada, two from The Netherlands, one from Cuba, one from Free China. I wonder if those people are here now. I would like them to stand up. (Applause)

From Cuba. (Applause) I think you were here last year, were you not?

And our good friends from Canada. We have quite a delegation here. (Applause)

And our visitor from Taiwan, which apparently is doing a big job in fertilizer. I am familiar with some of their work. The fertilizer developments on that little island of Formosa are very significant. They are doing an excellent job.

We hope that our friends from overseas will continue to come. We know there has been a large demand for the Proceedings of the Round Table from countries overseas. It shows the tremendous increase in interest in fertilizer technology which is occurring all over the world.

We have a minute for anyone who has a word to say for the good of the Round Table.

Mr. Wayne W. King: I have been asked by mutually minded and interested people to thank this committee for a teriffic job. I don't know how you are going to thank anybody for doing all that free work, but I will make this one little comment. There is a corporate investment here this week of pretty close to $7500 to $10,000 an hour. I think that is something. That is what is costs.

Chairman Sauchelli: On behalf of the Committee I want to thank all the men who have spent, I know, a great deal of time and energy in preparing their talks to present here. We regret that sometimes we have had to cut them short on time. I know that every one is serious in his preparation in order to present to you the benefit of his thinking.

We want to thank the whole membership for their fine spirit of cooperation. We hope that that will continue, because we need your suggestions for next year's program. If it is to be a success, it must have your cooperation. You have those cards which were handed out to you this morning. Please let us have your suggestions.

Don't depend on those cards. When you get home, if you have some fresh thoughts, jot them down and send them in to any one of us on your Committee. We shall be glad to get them. We need your help if we are to make the program a success next year.

So we will adjourn this 1958 meeting of the Round Table. I believe it was a grand success. Thank you all.

Index of Participants in Program

Bailey, Herbert P.
Chemical Engineer
Moores Lime Company
Springfield, Ohio

Bonn, David E.
Supervising Engineer
American Air Filter Company
Louisville, Kentucky

Bosman, T. J.
Federal Chemical Company
Nashville, Tennessee

Bridger, G. L.
Director of Ag. Chem. Research
W. R. Grace & Company
Washington Research Center
Baltimore, Maryland

Campbell, William F.
Field Engineer
Haynes Stellite Company
Claymont, Delaware

Castagno, Paul
Technical Service Representative
Spencer Chemical Company
Merriam, Kansas

Causey, Hubert E.
Technical Sales Engineer
International Minerals & Chemical Corp.
Skokie, Illinois

Crowder, John P., Jr.
Group Leader—Res. & Dev.
Virginia-Carolina Chemical Corp.
Richmond, Virginia

Daniel, John M., Jr.
Sect. Leader, Fert. Proc. & Mech. Div.
Virginia-Carolina Chemical Corp.
Richmond, Virginia

Daniels, Stewart D.
Manager, Technical Service
Monsanto Chemical Company
St. Louis, Missouri

Doelling, James E.
Vice Pres.—Industrial Sales
Bowser, Inc.
Fort Wayne, Indiana

Felch, Elroy L.
Engineer
American Agricultural Chemical Co.
New York, New York

Foote, William A.
Sales Representative
Dustex Corporation
Buffalo, New York

Franklin, Charles E.
Manager, Technical Service
Phillips Petroleum Company
Bartlesville, Oklahoma

Harwood, William W.
Ch. Chemist, Phosphate Chem. Div.
International Minerals & Chemical Corp.
Bartow, Florida

Henderson, Albert E.
Wilson & Toomer Fertilizer Company
Jacksonville, Florida

Hignett, Travis P.
Chief, Development Branch
Tennessee Valley Authority
Wilson Dam, Alabama

Hill, William L.
Chemist
U. S. Department of Agriculture
Beltsville, Maryland

Hoffman, Clair A.
Regional Engineer
Wheelabrator Corporation
Philadelphia, Pennsylvania

Jackson, Allen S.
Vice President
Fertilizer Equipment Sales Corp.
Atlanta, Georgia

Jacobi, William F.
Package Engineering Division
Union Bag-Camp Paper Corp.
New York, New York

Jessen, Jesse C.
Group Supervisor
Maintenance Engineering
E. I. du Pont de Nemours & Co.
Wilmington, Delaware

Jones, W.
E. I. du Pont de Nemours & Co.
Wilmington, Delaware

Jones, William E.
Manager, Fertilizer Division
Northwest Cooperative Mills
St. Paul, Minnesota

King, Wayne W.
Assistant Vice President
The W. S. Tyler Company
Baltimore, Maryland

Lang, George E., III
Head, Engineering Dept.
Edw. Renneburg & Sons Co.
Baltimore, Maryland

Leach, L. M.
Production Manager
Indiana Farm Bureau Coop. Assn., Inc.
Indianapolis, Indiana

MacDonald, Robert A.
Technical Service
Potash Company of America
Carlsbad, New Mexico

Madigan, James E.,
President
Fertilizer Engineering & Equipment Co., Inc.
Madison, Wisconsin

Major, C. J.
Technical Representative
Spencer Chemical Company
Atlanta, Georgia

Marburger, Grant C.
Technical Service Supervisor
Spencer Chemical Company
Kansas City, Missouri

Marshall, H. L.
Chief Chemist
Olin Mathieson Chemical Corp.
Baltimore, Maryland

Martin, Thomas E.
U. S. Industrial Chemicals Co.
Champaign, Illinois

Mautner, William G.
Fertilizer Research Director
Baugh & Sons Company
Baltimore, Maryland

Nielsson, Francis T.
Production Coordinator
International Minerals & Chemical Corp.
Old Orchard Road
Skokie, Illinois

Perrine, Elmer C.
Technical Service Representative
Nitrogen Division
Allied Chemical Corporation
New York, New York

Post, Nicholas K.
Manager, Industrial Applications
Airkem, Inc.
New York, New York

Prosser, Joseph L.
Manager, Service & Construction
The A. J. Sackett & Sons Company
Baltimore 24, Maryland

Retzke, F. A.
Smith Agricultural Chemical Company
Columbus, Ohio

Reynolds, J. E., Jr.
Oper. Mgr., Mixed Fertilizer Div.
Davison Chemical Company
Baltimore, Maryland

Robinson, Robert E.
Atlanta Utility Works
East Point, Georgia

Sachsel, George F.
Asst. Chief, Chem. Eng. Research
Battelle Memorial Institute
Columbus, Ohio

Sackett, Walter J.
Vice President
The A. J. Sackett & Sons Company
Baltimore, Maryland

Sauchelli, Vincent
National Plant Food Institute
Washington, D. C.

Schaffnit, W. E.
Stedman Foundry & Machine Co.
Philadelphia, Pennsylvania

Schmalz, T. R.
F. S. Royster Guano Company
Norfolk, Virginia

Schumacher, Carl P.
Technical Service Supervisor
Monsanto Chemical Company
St. Louis, Missouri

Sharp, Joe C.
Manager, Technical Service
Agricultural Chemicals
Spencer Chemical Company
Kansas City, Missouri

Shelby, Sam E.
Vice President
Federal Chemical Company
Louisville, Kentucky

Smith, Rodger C.
Head, Fertilizer Research
Eastern States Farmers' Exchange
West Springfield, Massachusetts

Spillman, Albert
General Manager
Fertilizer Mfg. Cooperative, Inc.
Baltimore, Maryland

Strauss, William I.
Chemical Industry Sales
Foxboro Company
Foxboro, Massachusetts

Tatum, H. Barnett
Technical Service Representative
U. S. Phosphoric Products
Indianapolis, Indiana

Tucker, Hubert H.
Sohio Chemical Company
Lima, Ohio

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