

# Preparation of Molding Sand via Mulling

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### ABSTRACT

*The "Simpson"<sup>®</sup> Mulling Machine as we know it today is a highly refined version of the vertical wheel muller long known and widely used in foundry sand preparation. Major modifications to the basic elements, the plows and the mulling wheels have been made. These modifications make possible the efficient usage of work forces essential to the preparation of the varied sands used in the modern molding processes. Extensive operating experience has delineated the most ideal application of the Batch and the Continuous Mulling Process.*

### Improved Machine for High Productivity

Over the past few years there has been a rapid growth of understanding among sand technologists. Basic sand research has accelerated as the needs of high production molding lines have become more demanding. The realization of automated foundry systems has necessitated a new approach to system sand preparation. Sand tonnage had to be increased while quality control was being tightened. This has not been easy and much praise should be given to the pioneers who contributed the numerous separate concepts. A great deal of new equipment had to be originated; that it was designed, built, tested and now operating is yet another laureate to our enterprising foundrymen.

Situated at the heart of the sand system is a new generation of mulling machinery, similar in appearance but differing in performance from the long known and used vertical wheel machine. The circular bowl, the agitating plows and the weighted, rolling, vertical, muller wheels remain the essential mechanical elements of the machine. The fundamental simplicity of the plow and vertical wheels could not be improved upon, but it was possible through experimentation to alter the arrangement of plow and wheel to achieve further improvements in mulling efficiency.

Shown in photographs are the transformations from the past to the present. A Foundry Machine is not built as a thing of beauty but as a device for utility. It is in the utility that the designer and user finds the satisfaction of its creation.

The Foundry Sand Muller is a very specialized production machine. To understand why the muller is constructed as it is, one must first understand the details of the sand mixing and mulling problem. The foundryman judges the muller by the sand it produces, but the muller manufacturer must understand elemental transformations taking place during the mulling process. An insight of the mulling process as it relates to foundry sand follows. If we were to imagine ourselves the Mulling Machine, we would more easily visualize the chore before us.

First we would not recognize the chemistry of the material we are to deal with but rather its physical properties. It is immaterial whether the molding mix be of silica sand or other aggregate, whether the bonding elements be organic or inorganic. The physical properties such as shear resistance, ductility, elasticity, plasticity are all important. The process is one of mixing via mulling. *Ideally, The Process Should Produce A Degree of Disorder, Such That When Sampled And Tested, The Mix Proves To Be Of Uniform Composition.*

The above has been very carefully stated since it encompasses both a definition and gives parameters to a process.

### Clay/Water/Glue Concept

It must be realized that many millions of varied particles are to be uniformly intermingled and surface coated with highly viscous bond. The almost infinitely large numbers of particles present dictates that the individual movements of the particles must adhere to the laws of mathematical probability. Although a perfection concept is not in keeping with practical realities, such a concept is needed to understand the process.

It is most helpful to visualize the sand aggregate as coated with an adhesive glue, which it is, when it is ready to be utilized as a molding media. It is the physical characteristics of the glue

which must determine the basic design and arrangement of the muller elements. A close study of the glue is required, if one is to understand the mulling process.

While many materials are available as damp glues, only a very few meet all the requirements of a casting process. The most common of these is made from water and clays of the bentonite group. It will suffice to discuss the bentonite water systems, since the characteristics of this glue encompass a wider range of physical property change than most others and the muller is only cognizant of the physical properties.

If one prepares a number of mixtures of 92.5 parts dry silica sand and 7.5 parts dry bentonite (parts by weight) and thoroughly mulls each with varied water additions, one will be able to produce a series of physical property curves which are well known in the technical literature, see Figures 1 and 2 (page 7). Of particular interest to this discussion is Figure 1, showing the effect of moisture on the resistance of the sand to ramming. It should be noted that at 2.6% moisture content the three ram density of the sand test specimen has reached its lowest value. This is due to bond strength being more ram resistant at this one moisture level. This Minimum Density Point is often referred to as the Temper Point. In the well mulled sand of Figure 1 at 2.6% moisture, the weight ratio of clay to water is very close to 3 parts bentonite plus 1 part water. In commercial practice this low ratio of water is seldom achieved since this perfection of water dispersion cannot be reached in the short mulling cycles used. The poorer the mulling, the more water required for temper. (Because the water resists being uniformly dispersed.)

If the bentonite plus water is carefully mulled without the sand, the clay water glue can be more easily examined for its characteristics. Figure 3 shows the tensile strength readings of the clay glue (at varied moisture) when it is squeezed into 1" tensile dog bone specimens. Note the maximum strength of the bentonite water glue matches the same 74% bentonite, 26% water found in the sand mix at its greatest resistance to ramming.

This then is the explanation for temper point or minimum density point. The clay water glue is strongest at a critical water percentage. Figure 2 showing compression strength with changing moisture under standard 3 rams did not indicate the highest strength of the sand mix at this critical 26% moisture level, rather maximum compression strength is at a much lower water level.

### Green Strength Testing

This seeming disagreement is of critical importance to a sound understanding of the meaning and interpretation of the commonly used A.F.S. standard Green Compression test. The standard 3 ram green compression test does not test the strength of the bond (or clay water glue) alone. Rather it tests the strength of a compaction of sand grains plus the glue. If the *glue is stronger*, the *density* of the compaction is lower and the green

compression strength suffers from a less dense specimen of fewer sand grains and less glue. As proof of this point, the specimen should be rammed not 3 times but as many times as necessary to achieve equal density at all water levels and then tested for the strength of the bond or glue.

This has been done as illustrated in Figure 4. Note the *highest* strength of the clay water sand mixture occurs at 2.6% moisture equal to the 26% water in the clay glue previously shown in Figure 3. The standard 3 ram green compression test is useful but it should be understood for what it really measures.

### Moisture Distribution or Temper

The problem in good mulling is one of achieving very complete water distribution. This is not easily accomplished since the clay water glue at or just above the temper point is a tough plastic like (similar to modeling clay) substance. Its adhesive glue property increases with water beyond the critical temper water while its cohesive strength decreases rapidly. Distribution of the water is more easily achieved in over tempered sand mixes and most commercial sand is over tempered. Slight over tempering at the muller is generally desirable since (1) Mulling cycles can be reduced to a commercial level in keeping with affordable mulling equipment. (2) Commercial sand systems cannot deliver the sand after mulling without moisture loss. (3) Most systems are at temperatures above ambient and lose water at and after the muller.

The ideal temper level for any sand molding system must remain that which accomplishes the many requirements of the type plant, metal cast and equipment used. The moisture is kept lower for most high production and automated systems, even so the moisture when leaving the muller will be above ideal temper.

### What is Mulling Efficiency?

It is most unfortunate that careless use of generalizations have beclouded the true situation as regarding mullers and their abilities. Such terms as high efficiency mulling belongs in the category of sales terminology rather than in the technical terminology. Any discussion of efficiency is relative and must involve quantity of clay, water and additives, power and rate of power usage, productive capacity vs. capital cost and maintenance required as related to a specific job. *Before any real measure of mulling ability is accepted, it is most important that a desired standard of water distribution be established.*

Our present conventional method using a 50 gram sample for moisture testing together with the insensitive balances used and the evaporative loss during handling and weighing, is crude.

On page 2 a definition for the mulling process was given. It should be noted the definition includes *sampling and testing*. Obviously the larger the sample of mulled product and the more

intensive the testing, the less the required mulling to achieve apparent uniform composition.

Any discussion of mulling and testing must carefully spell out sample size, number of samples and test sensitivity. Our present production sand testing procedures are much too crude for exact evaluation of production muller efficiency.

This must be a laboratory job done with great care in full knowledge of what a given test determines and in knowledge that, as yet, there is no one test suitable, *unless* it be a refined moisture distribution test, made on numerous small samples taken from various parts of the mix.

### System Sands Must Be Understood

Tests on all new clay, sand, water mixes, which can determine the uniformity of clay film distribution about the sand grains are meaningful, but it is a specialized interpretive process that *may or may not be relatable to a system sand*. Established pre-coated sand grains with their thick covering of active and inert clays together with decomposed organic and agglomerated fine silica are difficult to uniformly wet and not easily evaluated as to completed water distribution.

Actually at the completion of mulling an all new mix can be more easily evaluated and controlled but it is the system sands that need to be understood.

Improved mulling machinery when being developed, must be checked against the list previously mentioned:

- a. Capacity vs. Capital Cost.
- b. Power Consumption Per Unit Of Desired Sand Production.
- c. Wear Rate and Repair Time.
- d. Perfection Of Water And Clay Distribution.
- e. Reproducibility of Results.

Item e, not previously mentioned, is an all important consideration. One might think that having established a given mulling procedure, reproducibility should be expected, yet every foundryman knows that even with automated cycles and careful attention to details, *system shakeout sand does very widely batch to batch in moisture content, bond level and temperature*. No matter how a batch muller may be constructed, it can do nothing to compensate for changing proportions in composition of materials once charged to the mulling vessel.

The ideals of the laboratory, in total, cannot be applied in the shop. There are both practical and economic limitations which must be accepted. The muller manufacturer must be held responsible for incorporating those features which will result in

the best process control possible, within the imposed bounds of an economic operation. At the same cost a mulling machine can be built, having a *larger batch capacity* at a *lower RPM* for a *given connected horsepower that is equal in hourly output* to a *higher RPM*, *smaller batch capacity* of the *same* horsepower. This very basic decision is all important to the user as well as the designer of any proposed muller.

### Reproducibility

Reproducibility of product from the batch mulling process must deal with the following:

1. Quality control or control of reproducibility is a statistical control at best. The sensitivity of tests made, the number of tests taken and the number of batches represented by the tests establishes the quality or reliability of the so called Quality Control. Obviously, *fewer* samples are required if there are fewer batches being prepared.

The second step in this simple reasoning is that once an hourly capacity of sand is decided upon, it should be achieved by as few large batches as commercially feasible. Fewer large batches are more desirable than numerous small batches.

2. The return sand from a system varies in the storage compartment ahead of the muller. It contains stratifications which vary in temperature, active bond level and retained moisture. It is impractical to uniformly blend all the sand in the storage bin and for this reason, there will be greater variation in small local batch samples taken from the bin than will be the case for larger cross-section batches which give greater averaging. The simple reasoning here is that the larger the individual batch charged to the mulling machine, the more closely will be the average sampling. This is the second simple conclusion favorable to a larger batch size.
3. When batch size is determined for a given muller, to this batch must be added the bond. The amount of bond cannot be absolutely accurately determined since even large batches of system sand will vary in clay content but since the large batches are more consistently averaging there will be less variation in bond need. Secondly, a larger quantity of bond needed for a larger batch of sand is more accurately measurable since the measuring means will have a fixed pound or volumetric error. That is the error in bond can be percentage wise smaller with a large batch. This is the third simple conclusion favorable to larger batch size.
4. The most critical of all additives "water" is the most difficult of all to control. There are two major considerations:

- Measuring the exact quantity needed.\*

- Distributing the water uniformly to all particles of the clay on the individual sand grains.

The time allowed per cycle becomes a critical element in the all importance moisture control.

The logic supporting the case for the larger batch and the attendant longer cycle is conclusive.

There are no justifications for smaller batches and attendant shorter cycles since such reduces the opportunity of control and achieves no economic advantage.

*\*Either a man or an instrument must be used to select the correct amount of water. Both will use the same procedure. Part of the necessary water must be added, the mulling machine must distribute this amount, a sample is taken to determine the need for further water, a second addition, a further test and possible a third addition and another test. The closer the control of water sought, the more numerous the additions and the tests. Additional and tests take time whether by man or instrument. The longer the available time and the larger the batch size, the more accurate the control can be.*

The Simpson Muller as now manufactured has been carefully re-evaluated, its batch size has been kept large and in balance with a practical mulling cycle. Practical in that present day moisture controlling devices must have the necessary time to make accurate determination of the needed water with enough residual time in the cycle for the muller to accomplish good water distribution.

### Design Requirements For Sand Mulling

As has been pointed out, considerable work effort is required to obtain good water and bond distribution among and on the sand grains. Various types of motion and force effort have been experimented with and none has proven to be more effective per unit horsepower than that of shearing via compressing. The water and bond must be kneaded into a dough like consistency with development of adhesive glue properties such that the glue readily encompasses the sand grains. As mentioned before, the more water used, the weaker but more sticky the glue and the more easily and rapidly the distribution. However, *the correct temper level does not allow for this excess water. The muller must, therefore, be capable of exerting a considerable work force to cause the proper adhesion in the relatively dry glue bond.*

Various mechanical mulling elements can be envisioned to cause this result but in all cases the effective result was best achieved by use of a rolling, weighted wheel which can self compensate for both its weight and its position.

The action of the baker's common rolling pin is the closest simple approximation of the desired condition. When working a stiff dough mixture (similar but weaker than clay bond at the

temper point) it is necessary to knead or *roll out and reassemble* for uniform water dispersion. Depending on the strength and toughness of the dough, greater or lesser pressure must be exerted. When the pressure is too little, the dough does not shear; when too great, rolling pin penetrates completely through the dough to the supporting surface. *There is a correct work force for each type dough.* The same is true for the dough like bond in molding sands. As with dough, the sand, bond, water mix must be repeatedly compressed, sheared, reassembled to achieve the water bond dispersion.

During the development of the dough like consistency, the physical characteristics of the mix goes through progressive changes which require constant adjustment of the kneading pressure. The same is true of the sand mix. The pressure must start at a lower order and be increased as the mix becomes more resistant to compression shearing. To effectively do this, the rolling pin or muller wheel must compensate for the change as it occurs. Both the weight of the mulling wheel and the thickness of the compressed bed under the wheel should change as the physical strength of the sand mix develops.

It has been found desirable to construct the mulling wheel so that it can rise thus thickening the sand bed while at the same time the work force of the wheel is increasing. Note the height and weight of the mulling wheel in Figure 5. When the sand bond is in early stages of development and in Figure 6 at the end of bond development the mulling wheel is compressing and shearing a thicker bed using increased mulling force. Both the initial height and weight of the mulling wheel must be adjustable to suit the kind of sand mixture. *This initial adjustment is critically important since different sand mixtures require different work force.* A mulling wheel with too much force will completely penetrate the mix, thus becoming inefficient and acting as a blunt pusher while a weak mulling wheel will be unable to shear the mass and will fail to achieve good mulling. Nor can the wheel be fixed in relationship to the thickness of the compressed sand layer since the shear resistance becomes extremely high in thin layers, preventing shear.

When the mulling wheel is adjustable as to position and weight, it becomes the ideal device for the results desired. Its coefficient of friction with the sand is low, saving power and reducing sand abrasive wear.

The compressing shearing force should be spread over a broad area of the sand.

Narrow surfaces will treat only small amounts at each pass and will limit the degree of particle to particle displacement when shear occurs.

In the sand muller, the rolled and shear compressed cake must be fragmented and reassembled for the next pass of the mulling wheels. In the photographs shown in this text, one will note the

fragmenting lugs on the outside of the mulling wheels and the use of plows for gathering and directing the material back into the path of the oncoming muller wheel.

Because the desired process requires complete rearrangement of the particles, one to another, the plows must be designed to move some of the material forward in a circle while also moving the material from the center of the vessel outward and upward. The action must be one of always exposing new surfaces and new particles to the shearing action.

The present day Simpson Muller has been carefully proportioned and thoroughly tested to achieve the desired characteristics of an overall efficient machine.

### **Continuous vs. Batch Mulling**

There are now many Simpson Continuous Mullers serving the foundry industry. It was to be expected that these would find first acceptance in the high production automated foundries.

It comes as a surprise to many that this unique machine has improved the opportunity for sand control. At its inception it was credited with being capable of large tonnages, easily installed and operated. It was thought to be less adaptable to control than the Batch Muller. The very opposite has proved to be the case. As a system sand Mulling Machine, the Simpson Continuous "Multi-Mull<sup>®</sup>" is out-performing any and all batch mullers in achieving a new standard of product uniformity.

Verification of its performance is to be obtained in those plants where it is used. Explanation for this result is made below.

As previously discussed under batch mulling, the ideal situation would allow for the pre-blending of the entire shakeout storage bin before any mulling. This would considerably reduce the wide variations in the stored sand. Adjustment of water or bond to gradual change is easier than to sudden change. The unique Figure 8 design of the Multi-Mull results in a constant back-blending and averaging of the variables introduced with the incoming sand. The machine acts as a small storage bin whose sand is being constantly blended while being mulled. As

temperature and moisture swing back and forth from the shakeout source, their effect is leveled out due to the back-blending and averaging in the Multi-Mull.

The demand for temper water is at a near constant rate.

Temperatures tend to mount slowly over minutes on morning start-ups and then settle to near constant values as the molding and shakeout becomes steady. The moisture control is easily achieved. The discharged sand is found to be *far more uniform in moisture, temperature and bond* than from the more variable batch process.

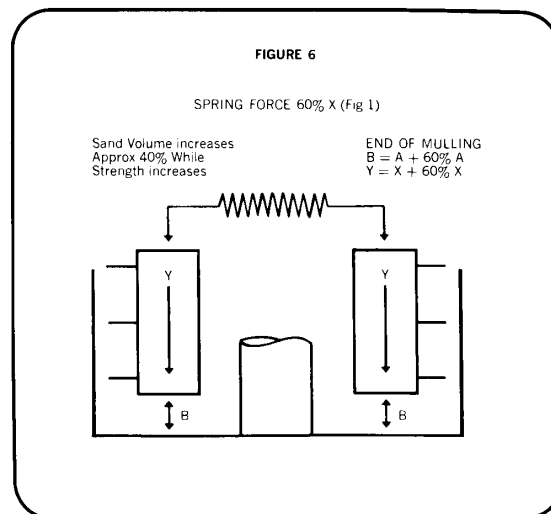
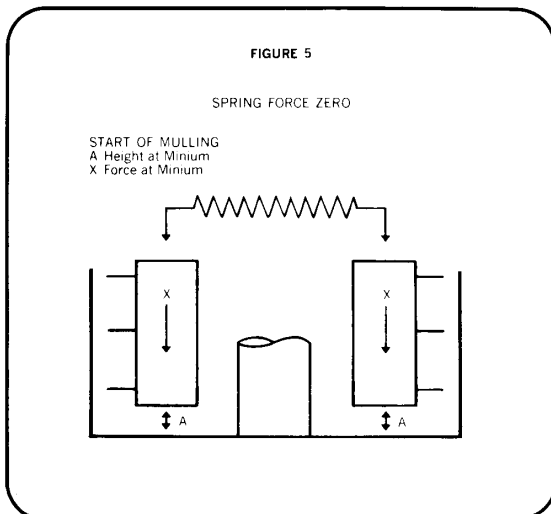
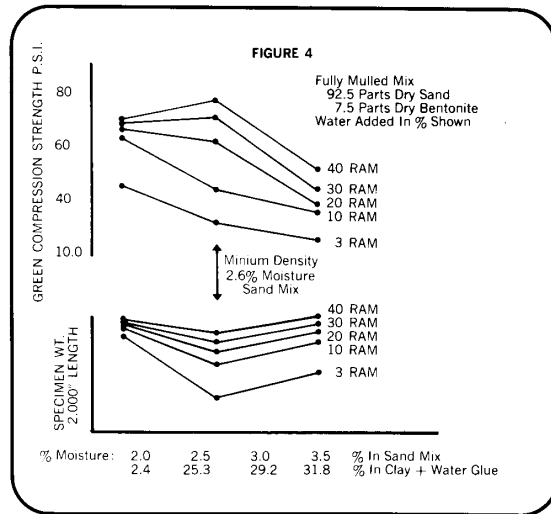
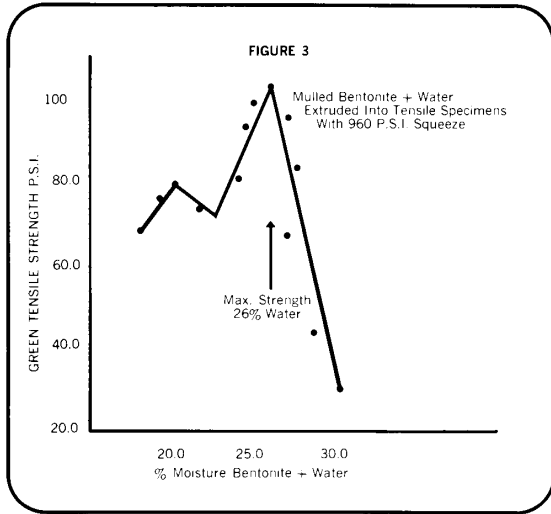
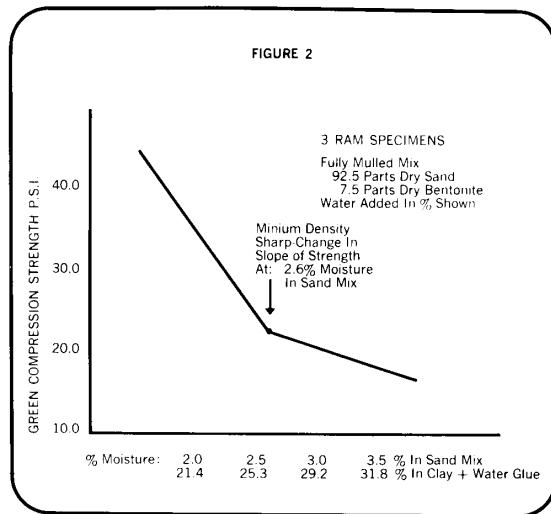
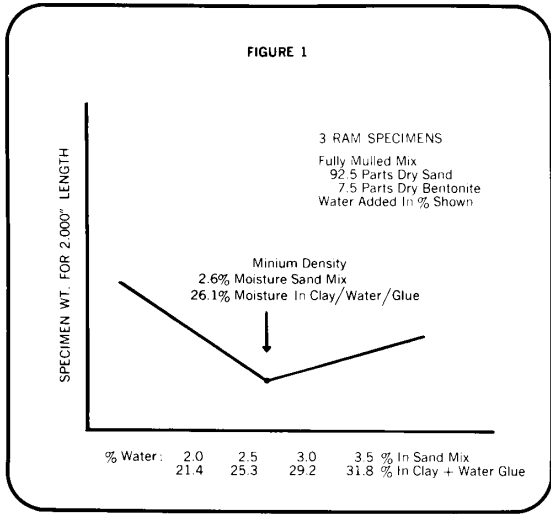
Aiding the uniformity is the simplicity of the operation. The Continuous Machine instantly stops and starts on demand to meet the sand requirements. There is no need for time cycling or complex base water injection systems. The simplicity of the moisture control and all other controls reduces the probability of operational malfunction.

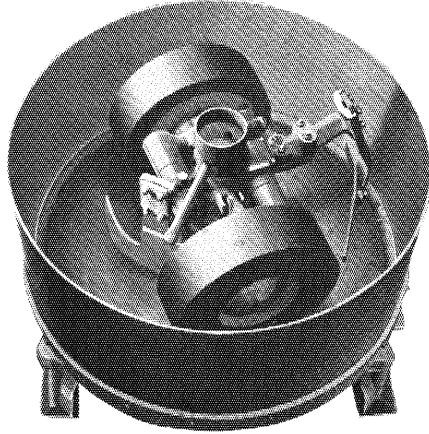
The manufacturing cost of a mulling machine closely relates to the designed load torques. The batch machine must cycle from no load to peak design torque such as that only a part of the paid for work effort can be utilized. The continuous muller uninterruptedly and continuously applies the paid for work effort so necessary to the mulling process.

These machines are made in a variety of production sizes and are used in all types of metal. They are now used in small non-automated molding systems.

Recent modifications in these machines make them adaptable to almost any kind of mixtures other than shell sands, but for the *smaller capacities of special sands* the batch muller still remains the more economical purchase.

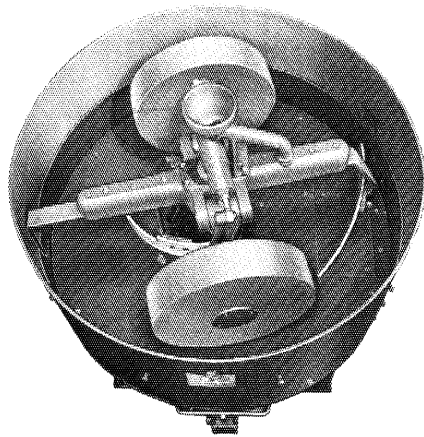
Continuous processing has always appealed to any logic which seeks lower operating cost and simplified quality control. Continuous Mulling will grow into ever widening usage. The summation for Continuous vs. Batch Mulling might be stated as follows: "The grains of sand taken from the Continuous Mulling Sand System look and behave like those taken from an exceptionally well controlled batch mulling system."





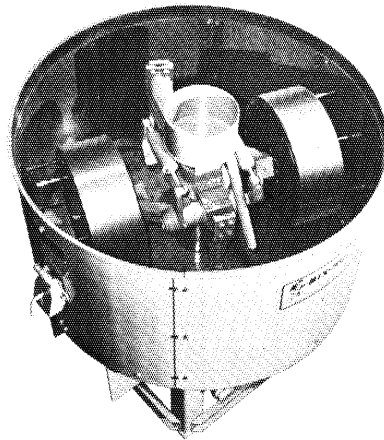
**MODEL UD  
SIMPSON MIX-MULLER**

The first Mix-Muller  
with motor and speed reducer  
mounted on the bedplate.



**MODEL F  
SIMPSON MIX-MULLER**

A design incorporating lightweight  
spring loaded mullers.



**MODEL G  
SIMPSON MIX-MULLER**

With individually sprung mullers,  
higher operating speeds  
and greater batch capacities.