

## Application #500

# Technique of Mulling-- Muller Modifications

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### Abstract:

*This report deals with a definition of mulling, investigation of mulling techniques, modification of muller design to intensify mixing and mulling capability. Test data confirming design improvements is presented. Details of design change to achieve the best balance between economic productivity and sand quality control are described.*

**Introduction** -- The accelerated development of the foundry industry imposes new problems on the sand preparation equipment now available. The progress of the foundry industry has been rapid and marked by enormous casting quality improvement together with large increases in productivity per man hour. These changes require a continued upgrading of prepared foundry sands. Further increases in casting quality are required and to be expected. While metallurgical knowledge has advanced more rapidly than has the knowledge of molding sands, the sand technology is now undergoing a most rewarding period of study.

With the advent of high speed automated molding-frequently referred to as "High Pressure Molding" - the variable properties of molding sands have been more fully expanded, and found wanting. The necessary property compromise between a sand that will best mold, produce quality castings, most easily shake out, and readily handle through the various mechanical transporting devices must be found.

It has become self-evident that the lip service previously given to sand quality control must give way to active application of strenuous control techniques.

A major consideration in future control programs deals with the preparation of the sand in the mulling machine. The machine of the future must prepare large volumes of sand, but not at sacrifice of quality control. Actually improved control is possible, and must be attained. To this end, a program involving both laboratory and shop testing of mulling was undertaken. The objectives sought

were intensification of productivity, and more reproducibility of sand properties.

**History** -- In the early days of the foundry industry, sand mulling was limited to blending of natural sands with fire clays, natural resins and molasses. Because the more important castings were then made in dry sand molds, green properties and moisture control were of lesser importance.

With the introduction of bentonite and washed silica sands, the era of synthetic green sands opened. Coupled with the new source of raw materials, there came about a demand for improved mixing machinery. Various sand mixing devices were utilized, each in keeping with the then developed art. As time progressed, the sophistication of the art, most of the simple mixing devices were replaced by the more effective mulling machine. The mulling machine had the mixing machine features of displacement plows, but in addition made use of the rotating wheel as a device by which compression and shear (smear) was induced.

From time to time, the muller type mixers were altered in mechanical design to improve efficiency and to reduce the maintenance. Variations of the rotating wheel were attempted. Some using greater force, high

R.P.M., wider and narrower wheel tread. From all of these attempts has developed the present day acceptance of a principle. The use of a wheel tread to induce smearing has become synonymous with the term mulling.

While mechanical improvement is always desirable, the probability of a major break-through toward an entirely new way of doing the necessary work on moist sands is unlikely. This is easily resolved, since man has not yet found other than four fundamental machines the pulley, wheel and axle, inclined plane or wedge and screw.

The possibility of the application of the pulley to the mixing of sand is remote. The screw, together with the inclined plane, has been used in variations of the common pug mill for many years. The wheel and the incline plane (plows) in variations are used in the muller. The combination of the wheel, incline plane (plows) moving in a screw like pattern have been tried but with only limited success because of the same basic disadvantages attributed to the pug mill. The screw progresses the sand in a continuous direction, eliminating the possibility of that material which is just behind, mixing with that which is just ahead. To achieve success with the screw, one must visualize supplying the screw with absolute uniform proportioning of sand, bond and water as a steady uninterrupted flow. While this possibility exists, it unnecessarily exaggerates the problem of sand preparation.

By utilization of a stationary round cylinder (mixer bowl) and by movement of differently angled wedges (plows) for dividing and mixing, highly stratified charges of sand, bond and water can be blended into a common mass composition. When to the cylinder and moving plows one adds the revolving wheel, one has probably utilized the best practical combination of the fundamental machines known. It remains to achieve the very best application of the wedge and wheel for further progress in efficient usage of power, reduced maintenance, higher productivity and closer control of output quality.

**Terminology** -- Some of the terminology associated with molding sand production can have different interpretation. For the purpose of clarity the following terms have been given definition in keeping with the intended meaning expressed in this report:

*Mixing or Blending* Intermingling of unlike particles such that alike average composition is attained; in the case of molding sands, this is a physical act only, rarely are chemical reactions involved. The physical act of mixing can be accomplished by various motions which result in division and displacement of one particle in relation to another unlike particle. The act is coupled with work being done since matter is moved. The amount and rate of doing the work is a function of the degree of adhesion between the unlike particles and the cohesive strength of the bond use (example clay).

*Mulling:* The extension of mixing, resulting from intensification of the work forces. Application of work forces to cause kneading, smearing, compression and shear. The work forces applied via the tread of a following weighted wheel. The weight force of the wheel being adequate to compress and rupture adhesive and cohesive films which would otherwise cause agglomerates of unmixed material to move enmasse in simple mixing. The strength of the films will control the amount and duration of the mulling necessary. The simple act of compression alone being less effective than compression followed by shear (smear). The rolling wheel should twist either by erratic motion while rolling or more simply by skidding around a fixed radius while supported by the sand, the sand in turn supported by a flat roadbed.

*Aeration:* The fragmentation of large agglomerates, reducing their size. Incidentally reducing the bulk density by loosening the packed agglomerates, thus increasing the air porosity all of which contributes to more uniform flow about a pattern.

*Moisture Control:* The achievement of a desired quantity of diffused water. The control can be at a pre-established weight percentage of the mix or a quantity of water which will accomplish a desired set of physical properties, commensurate with the clay and other additives present.

*Moisture Control Device:* A device which samples the sand and evaluates its condition relative to the water present. The device will cause flow of water as needed into the muller.

*System Sand:* A foundry sand which recycled through the sand system being alternately mulled, molded, poured and shaken out, with new bond additions limited to less than 1% of the sand mulled on each recycle.

*New Sand Facing:* Entirely or nearly entirely of new unbonded sand to which is added 5% or more of new clay.

**Qualification Testing** - A complete analysis of the abilities of a mulling machine involves a large number of evaluations. The most important of which are:

1. Control characteristic, adjustability to product
2. Initial cost per ton product
3. Maintenance cost per ton product
4. Power consumption per ton product
5. Supplemental equipment or manpower requirements

To achieve the best balance of all of these characteristics, compromise must result. For example the rate of doing the work must be balanced against the batch size, the rate of wear, the power consumption and the controllability. Tests increasing the R.P.M. of the machine demonstrated increased power requirement and increased wear rate of the moving parts. Increased R.P.M. and subsequent shorter cycle time decreased moisture controllability and possible batch size in a given mixer.

Since the cost of a machine is tied to the design as determined by the power to be applied, it becomes essential to achieve the minimum power input for the maximum sand output. Reducing the retained load or batch to hold the design within reasonable power input can be considered but results in serious disadvantages. The small retained load or batch size, coupled to shorter cycle times will result in penalties as follows:

- a) Shortened cycle means less time for close moisture adjustment and overall poorer moisture control.

- b) Larger percentage of the total cycle devoted to non-productive charging and discharging.
- c) More frequent no load to full load on the operating mechanism inducing more rapid gear wear and fatigue failure of parts.
- d) The smaller batch results in poorer averaging of large variables in shake out return.

These disadvantages suggest that there must be an optimum between batch size, cycle time, machine size and power. This optimum was sought and believed achieved. Figures 1, 2 and 3 illustrate the general relationships found and applied.

While the mulling of both system sand and new sand facing can be achieved in the same basic muller, there is a marked difference in mulling intensity requirement. The system sand preparation requires that the correct amount of water be uniformly diffused while a relatively small amount of new bond is being dispersed. The new sand facing preparation require that large quantities of new bond be dispersed together with water diffusion. The preparation of the system sand generally requires less power and less time to reach a state or property equilibrium.

**Optimum Cycle Time** -- Not only economics but problems of property control establish a practical minimum cycle for mulling. The water content of sand mix is all important to the physical properties attained. Since the water content (unlike the bond) cannot be a constant additive but must vary with the temperature and base moisture of the material charged, a sensing (man or instrument) device must constantly evaluate and correct to achieve the ideal water content of the sand.

*Table A* shows the sensitivity of 7-1/2% western bentonite sand to variables of water content and mulling. The problem of achieving a near exact water control is one of great difficulty.

The process of adding water to a mulling sand is one of adding less water than ultimately desired and by steps of further additions and testing reaching a final correct addition. Whether this process is conducted by man or instrument, the process properly carried out takes considerable time. Of all the problems involved in producing a controlled sand, non deserves more considered attention than that of moisture control. When water is added, a time elapse, before testing, must be allowed. If the cycle is too short, either a man or instrument is rushed to make judgement before diffusion is complete and sand is frequently discharged before the trim water has been completely mulled into the sand.

Observations of numerous muller installations has shown that regardless of the type of muller, mulling cycle times of less than 90 seconds (1-1/2 minutes) are inadequate for ideal moisture control and diffusion. Neither a man or moisture control device

can complete accurate sampling and water addition early enough to allow for complete mulling of the last water added.

While mulling cycles are normally timed from the addition of the sand and bond into the muller, actually mulling time should only start after all ingredients including all of the water has been added.

After a survey of various foundry muller operations, it was considered desirable to accept the 90 seconds or 1-1/2 minutes as the minimum desired cycle when evaluating muller capacity.

**Range of Testing Conducted** -- Variations in the following were tested while measuring power usage, capacity per hour, rate of property development.

1. R.P.M. of the plow and mulling assemblies.
2. Muller -- face width, diameters, weights, heights from pan suspension.
3. Plows -- number, angle width, location.
4. Water injection, above sand, below sand, gravity and pressure feed.

The resulting test data is far too voluminous and detailed to report here, having been collected over many months of testing. The conclusions reached, made possible the construction of a laboratory prototype of a far more effective muller. This new "G" Series Simpson has better than twice the hourly capacity of its predecessor, the Model (F), with only 1/3 more connected horsepower. The batch or retention of sand has been increased by at least 25% while the mulling time has been reduced by at least 50%.

Fig. 1—R.P.M. Vs. Power Consumption

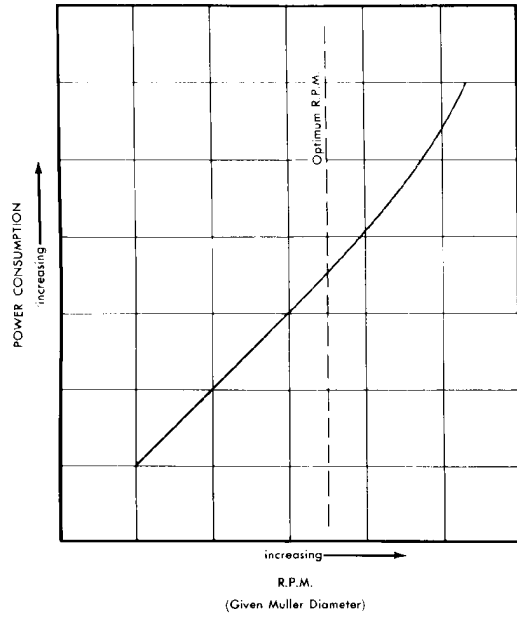


Fig. 2—Batch Size Vs. Power Consumption

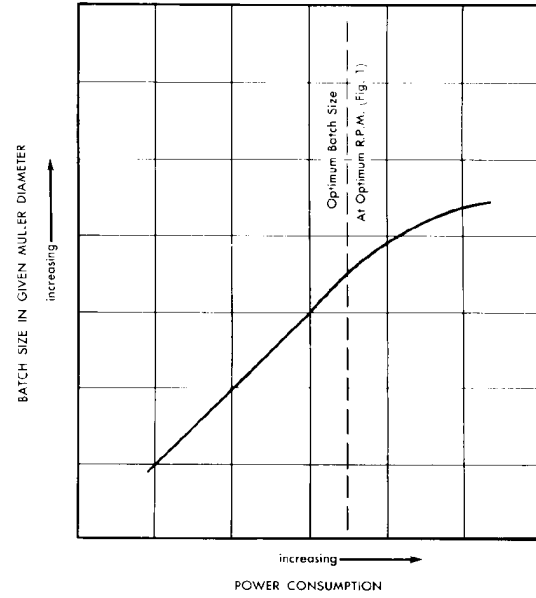
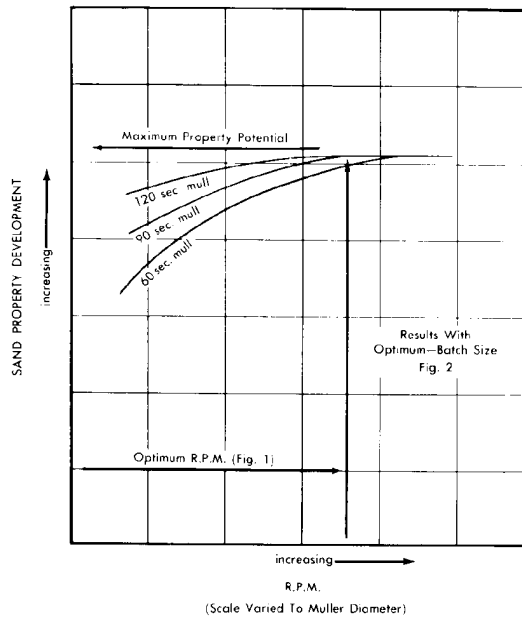


Fig. 3—Property Development Vs. R.P.M.



**Table A - System Sands**

Units of Mulling Effort	Properties	% Moisture				
		2.0	2.2	2.4	2.8	3.2
1	WT. 2" Specimen - grams	163.0	164.1	163.8	163.2	162.7
	Green Compression - psi	14.9	14.9	15.3	15.5	15.3
	Dry Compression - psi	54	61	70	73	92
2	WT. 2" Specimen - grams	163.9	164.3	162.8	162.1	159.6
	Green Compression - psi	18.2	19.6	19.2	16.7	11.8
	Dry Compression - psi	73	76	80	96	135
4	WT. 2" Specimen - grams	164.3	162.4	157.1	156.6	158.8
	Green Compression - psi	21.7	20.7	16.4	12.5	10.5
	Dry Compression - psi	72	76	97	117	147
8	WT. 2" Specimen - grams	163.1	156.8	154.4	155.6	158.1
	Green Compression - psi	27.7	19.3	15.3	12.2	10.2
	Dry Compression - psi	68	77	88	107	148
16	WT. 2" Specimen - grams	162.5	156.2	153.4	154.6	157.7
	Green Compression - psi	25.3	20.1	16.5	12.6	11.4
	Dry Compression - psi	65	71	85	112	146

**NOTE:** Dry Weight of Mix:           92.5% Ottawa Silica Sand -- 67 AFS Fineness  
   7.5% Western Bentonite

**The principal changes made for the "G" Series are listed and described below:**

1. Crib height and crosshead clearances were increased to allow for a larger retention of sand.
2. Plows were reduced in face width and streamlined to eliminate non-effective forward carry while increasing the mixing by enhancing the division and displacement.
3. Rotation rate was increased to induce more rapid mixing of dry ingredients with water so that the mulling wheels could become effective earlier.
4. Mulling wheels were altered in face width, weight and suspension resulting in greater mulling intensity. The new suspension makes possible a very wide range of adjustability for either wheel. Regardless of the type sand the wheel can be arranged to properly compress and shear. The wider muller track compresses and shears more sand on each pass.
5. The mull sand cake from beneath the wheels is disintegrated by aerating devices attached to the side of the wheels. These

aerating lugs have the added ability to aid in the blending as well as limiting sand build up on the crib wall.

6. New bond injection devices for introducing the bond under the sand have been developed.
7. In the continuous muller a new self-compensating discharge mechanism assures that discharge can be limited to sand directly off the pan and from under the muller wheels. This eliminates any question of ability of the sand to short circuit to discharge.
8. The connected horsepower has been increased by 1/3 on all muller sizes but the output of the machines has been doubled.

Foundry field tests have been conducted, the results justify all laboratory anticipations. This new muller advances sand mulling to newer and higher plateaus of efficiency.