

12

EUROPEAN PATENT APPLICATION

21 Application number: 82302460.9

51 Int. Cl.³: **B 02 C 23/06**
B 02 C 19/12, B 02 C 25/00

22 Date of filing: 14.05.82

30 Priority: 02.06.81 CA 378877

43 Date of publication of application:
 08.12.82 Bulletin 82/49

84 Designated Contracting States:
 BE DE FR GB IT NL SE

71 Applicant: **GENERAL COMMINUTION INC.**
 1993 Leslie Street
 Don Mills Ontario M3B2M3(CA)

72 Inventor: **Gandolfi, Eduardo Angel Jose**
 46 Harrington Crescent
 Willowdale Ontario M2M 2Y5(CA)

74 Representative: **Jones, Andree Zena et al,**
E. N. Lewis & Taylor 144 New Walk
 Leicester LE1 7JA(GB)

54 **Comminution process.**

57 Commiution is carried out in a mill with a positive transport capability, upon a solid in a mixture of a pasty or cohesive consistency. The efficiency of comminution, in terms of the fineness of the powder produced, and of the power needed to produce it, is maximised by controlling the amount of liquid in the mixture. The mixtures examined are of coal in water, coal in oil, zinc in water, mica in water, and limestone in water.

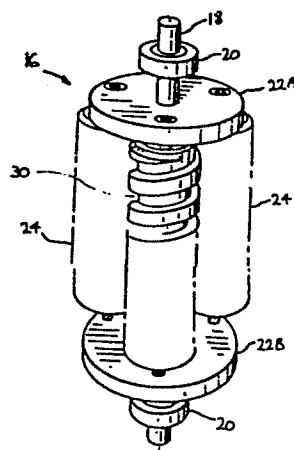


FIG. 2

TITLE: COMMUNITION PROCESS

 The invention relates to a process for
comminuting a solid in a mill. The solid may for
example be coal, which needs to be comminuted
before being fed into a steam boiler.

5 When a liquid such as water is added to
a solid such as coal, the mixture has a consistency,
when comminuted, that depends not only on the size
and shape of the solid particles, but also on the
quantity of added liquid. When dry, or nearly dry,
10 the mixture flows easily like a powder when poured
or otherwise allowed to fall; when very wet, again
the mixture flows easily, being predominantly liquid.
Most mixtures have an intermediate stage at which
the mixture substantially does not have the property
15 of being able to flow freely. Now, the particles in
the mixture adhere to each other, or agglomerate;
the mixture is pasty, in that it is like a solid
to the extent that it is capable of holding
itself in a shape, though like a liquid to the extent
20 that it has virtually no structural strength. An

example of such a mixture is a mixture of sand and water of a consistency suitable for the building of sand-castles. For the purpose of this specification, the particles of solid are said to cohere with each
5 other in such a mixture, and the mixture itself to be cohesive.

When a mixture is passed through a mill, the time it spends in the mill (termed the "residence time") is usually an important factor in determining how finely
10 it is comminuted. If the mixture is such that it flows, then gravity is what determines how quickly the mixture goes through the mill. If the mixture is cohesive on the other hand, then if the mill is provided with channels that move as the mill is operated, the
15 residence time that the mixture spends in the mill can be altered. By a careful selection of the speeds of the mill, and size and rate of movement of the channel, a cohesive mixture can be caused to remain indefinitely in the mill, or to feed upwards
20 through the mill against gravity, or to feed downwards at a rate greater than that due purely to gravity. In a mill without such channels, even a cohesive mixture travels through the mill under the action only of gravity, and of whatever frictional or viscous resistances to
25 motion may be present.

For the purpose of this specification, a mill that has such a movable channel, so that it is capable of transporting cohesive mixtures, is said to have a transport capability. If the channels are
5 arranged to transport the mixture in a direction to assist gravity, or whatever other agency feeds the mixture into and out of the mill, to urge the mixture through the mill, the transport is termed positive. If the channels are arranged to transport the mixture
10 against gravity, on the other hand, the transport capability is a negative transport capability.

It is recognized in the invention that a mill with a positive transport capability allows cohesive mixtures to be milled economically. Without positive
15 transport, such mixtures tend to remain in the mill because the particles of solid tend to cohere not only to each other but to the mill itself. Some mixtures however, such as some foodstuffs, have in the past had to be milled at a very sticky consistency, and it has been
20 necessary in such cases, in order for the mixture to pass through the mill, to provide for a positive feed capacity for the mill. By analogy with the positive transport capability described above, a positive feed capacity is one in which a pressure is exerted on the
25 mixture to push it, or even to suck it, through the mill from inlet to outlet, in the event that gravity is ineffective to do this. However, the provision of such a pressure carries with it the requirement that the mill remains full, for no voids can appear in the

mixture if it is to be fed under pressure. Whilst it is possible, and economical, to comminute in that way some mixtures such as food substances (e.g. chocolate), other mixtures (such as coal and oil)

5 are so stiff when cohesive that the power consumption needed to operate a mill that is full of that mixture would be wastefully large. In the invention, the positive transport capability allows the mill to be used on mixtures that are so cohesive that they would not

10 otherwise move through the mill unless pressurized, yet the positive transport capability allows the mill to transport such mixtures without the mill needing to be full of the mixture.

It is possible to comminute mixtures that are

15 too sticky or too stiff to be moved by gravity, by batch comminution. Here, a batch of the mixture is placed in the mill when the mill is stationary, and is removed from the mill when the mill is once again stationary, after comminution.

20 Thus, batch comminution needs no transport, and no feed, capability in the mill, so that again the mill need not be full during comminution.

Batch comminution is however much less economical than continuous comminution, to which the invention

25 is mainly applicable.

It is further recongized in the invention that when the process of comminution of a solid is carried out on a mixture that has a cohesive consistency, and when the comminution is carried out in a mill having a positive transport capability, then the efficiency of comminution depends upon the amount of liquid that has been added to the solid to form the mixture. According to the invention, it is preferred that the comminution is carried out using a mixture having the liquid content that maximizes the comminution efficiency.

In the invention, the efficiency of comminution that is referred to should be understood as being not confined to any particular measure of efficiency. What is most efficient usually is dependent on what is most economical, which can depend on a variety of factors.

In the particular case therefore, the miller has in mind a criterion by which the efficiency or economy of the comminution in that case is to be measured. Sometimes for example the criterion of economy will be the compromise between the fineness of the comminuted powder and the power consumption of the mill (and such a compromise will differ in dependence on the change in price of electricity from area to area); sometimes, as another example, the criterion

of economy will be the fineness of the powder as compromised by the capital cost of the mill required to produce that degree of fineness in a given throughput rate of the solid.

5 Whatever the criterion of economy in a particular case is, the invention provides that experiments are carried out to measure how economical (according to that criterion) the comminution is at varying added liquid throughputs. If the experiments
10 show that there is a liquid throughput that gives a maximum level of economy (according to that criterion), then that throughput is used when comminuting the solid under the particular conditions of the case.

 Of course, there are factors other than the
15 quantity of liquid throughput that also have an effect on the efficiency of comminution. It is important therefore to keep all the other factors constant whilst varying the added liquid throughput during the experiments.

20 In the experiments that are reported below in this specification, a measure of efficiency that was of particular interest was the proportion of the comminuted solid that would pass through a mesh of a given fineness. Another measure of efficiency that
25 was investigated was the proportion of the comminuted solid passing a given mesh divided by the power consumption needed to drive the mill.

-7-

Experiments have shown that the fineness of the comminuted solid produced by the mill varies with the quantity of liquid added to the solid throughput. This effect is unexpected in that

5 the experiments show that the maximum fineness appears to correspond, though somewhat loosely, with the mixture being at its most cohesive. The (electrical) power required to drive the mill to comminute the solid varies also with the added liquid throughput,
10 being at a maximum when the mixture is at its most cohesive.

The invention will now be further described, with reference to exemplary embodiments, as illustrated in the accompanying drawings in which:

15 Fig. 1 is a plan of a mill;

Fig. 2 is a perspective view of part of the mill of Fig. 1;

Figs. 3 to 10 are graphs showing how the various ordinates are a function of the amount of
20 liquid throughput added to the solid throughput passing through the mill.

The mill 10 shown in Figs. 1 and 2 comprises a housing 12 having an inner cylindrical surface 14. The housing 12 is part of the fixed frame (not shown)
25 of the mill 10.

A rotary assembly 16 is located inside the housing 12. A shaft 18 is driven by a motor (not shown), and runs in bearing 20 housed in the fixed

frame. Keyed to the shaft 18 are drive plates 22. Mounted between the drive plates 22 are three rollers 24, which can rotate freely with respect to the plates 22 about axes parallel to the shaft 18.

5 When the shaft 18 is rotated, the plates 22 rotate in unison with it, and the rollers 24 roll around the surface 14 of the housing 12. The rollers 24 run on axles 26 which are flexible in some degree, so that the force with which the rollers 24 press
10 against the surface 14 is largely the centrifugal force due to the rotation of the rotary assembly 16. Friction at the point of contact between the roller 24 and the surface 14 means that there is substantially no slipping at that point, and the roller 24 accordingly
15 rotates in the opposite sense to the shaft 18.

 To operate the mill, the mill 10 is mounted with the shaft 18 vertical, and the solid to be milled is fed into the top of the mill, onto the upper one 22A of the drive plates 22, from a vibratory hopper
20 (not shown) or other suitable feed device. The liquid is conveyed through a pipe (not shown) also into the top of the mill. The mixture falls down into the annular gap 28 between the plate 22A and the surface 14; is milled by the rollers 24 against the surface
25 14 as it passes down through the mill; and finally passes out through a corresponding gap between the bottom plate 22B and the surface 14. The milled mixture is collected in a hopper (not shown) or other

suitable collecting means placed below the mill.

The mill has a positive transport facility, as called for in the invention, in that the rollers 24 are each formed with a helical groove 30, comprising
5 a transport channel. When the rotary assembly 16 rotates, the grooves 30 will tend to transport the substance in the mill either up or down depending on the direction of rotation of the assembly 16. A number of factors influence the extent to which the grooves
10 impose this transport effect on the substance.

The first factor is the consistency of the substance. Both gravity, and the grooves can have an effect on the transport rate of the mixture through the mill. If the mixture is very dry, then most
15 mixtures tend to pass through the mill under gravity, the grooves having only a comparatively slight effect. This is particularly the case with dense materials, such as metals and ores. With light, fluffy, materials, such as pieces of paper, the grooves can
20 significantly affect the transport rate even though the material is dry. Equally, if the mixture is very wet, in that it is of a very thin and runny consistency, then again the substance tends to fall through the mill under the action substantially only of gravity. When,
25 on the other hand, the mixture is a thick, pasty, sticky, cohesive mixture, the mixture can support itself to a certain degree, and the grooves can now be extremely effective in setting the residence time

that the mixture spends in the mill.

Once the consistency of the mixture is such that its residence time is dependent on the presence of the grooves, then the residence time is also affected
5 by the other factors, which include the configuration of the grooves, the number of starts, the lead and pitch of the helix, the flank angle of the sides of the grooves, the diameters of the rollers and of the housing, and the speeds of rotation of the rollers
10 and shaft.

If the mixture were too wet or too dry, it would not remain long enough in the mill to be comminuted very effectively. If it were too cohesive then without the positive transport effect the mixture would stay
15 in the mill indefinitely. The positive transport capacity allows the controlled comminution of cohesive mixtures.

It is necessary though that if the grooves do create the positive transport effect, they do not become clogged. The rotary speed of the rollers should be high
20 enough that centrifugal force flings the material out of the groove, to empty the groove at least partially. Thus the material in the groove is constantly changing. If the mixture is extremely cohesive, it may be that the groove is so arranged that it cannot be emptied at all:
25 when the groove on the roller rolls over a point on the

wall on the housing the mixture is packed so tightly into the groove that it is not flung out by centrifugal force. Such a fault is not cured by increasing the speed of the mill, since that causes the mixture to
5 be packed even tighter. It is necessary in such an event to increase the size of the groove, or to provide the sides of the grooves with a flank angle.

The positive transport feature in the kind of mill illustrated in Figs. 1 and 2 may be
10 regarded as an axial screw conveying capability. In other mills, the positive transport feature may be provided somewhat differently, but essentially it requires the presence in the mill of a channel which travels, when the mill is operating, in a direction
15 to hold the mixture in the mill for a longer or shorter time than it would remain in the absence of the traveling channel.

-12-

Turning now to the manner of use of the mill in the process of the invention, an experiment is first carried out as follows. A given quantity of the solid that is to be milled is passed through the mill in a dry condition, at a predetermined rate. The speed of rotation of the mill, and the amount of electricity used by the motor to maintain that speed, are both noted. The milled solid is collected and measurements taken of the particle size prevailing in the substances.

The experiment is repeated, but this time a quantity of liquid is mixed with the solid. The rate at which the solid is passed through the mill is kept the same as before, so that the total aggregate quantity of both solid and liquid passing through the mill is increased by the added quantity of liquid. Again, the particle size of the milled solid is measured, together with the power consumption.

Further experiments are carried out, in which more and more liquid is added to the solid that is to be milled.

Figs. 3 and 4 are graphs showing the results of these experiments, which in this example were carried out on a mixture of coal and water. The quantity of coal fed through the mill was the same throughout the experiments, and was 720 kg/hr. The shaft was driven at a speed of 1250 rpm. In Fig. 3, the vertical scale is the proportion, expressed as a percentage, of the 720 kg/hr. throughput of coal that was milled finely enough to pass through a mesh of a predetermined size, which in the case of curve A was a 100 mesh; curve B, 200 mesh; and curve C, 325 mesh. In Fig. 4 the vertical scale is the measured power consumption of the electric motor driving the shaft.

It can be seen from Fig. 3 that the fineness of the milled coal is at a maximum when the throughput of coal (i.e. the 720 kg/hr. mentioned above) was supplemented by a throughput of just under 40%.

Such a graph as Fig. 3 naturally may be drawn for any mixtures of solids and liquids. It is recognized in the invention that if the graph exemplified by Fig. 3 should display such a maximum as is displayed by Fig. 3, then that maximum is useful in determining what the consistency of the mixture should be to provide the most efficient milling; the most efficient, that is, as determined by the prevailing fineness of a given throughput.

The mixtures on which the experiments have been carried out have all displayed or have indicated such a maximum as that exemplified by Fig. 3. The mixtures were: coal plus water (as described above);
5 coal plus oil; mica plus water; zinc plus water; and limestone plus water. The percentage of added liquid at which the maximum solid fineness is produced was found to vary, in a somewhat unpredictable way. Fig. 6 shows the corresponding graph to Fig. 3 for the mixture of
10 limestone and water, from which it can be seen that the position of the maximum, and the profile of the graph at the maximum, may even vary with the level of fineness that was chosen as a measure. The upper curve A, is that for 100 mesh, or 150 microns; the middle, B, is
15 that for 200 mesh, or 75 microns; and the lower C, is that for 325 mesh, or 45 microns. The mixture consistency needed to produce the maximum fineness therefore depends not only on the speed of the mill, the throughput rate, the configuration of the helix, and so on, but also
20 on the actual measure of the fineness itself.

It was found in the experiments with zinc and water that when very dry, milled particles of zinc tend to agglomerate, thus negating the milling process. Zinc has to be slightly wet for it to be milled successfully
25 at all. Factors such as this will affect the shape and

position of the maximum on the graph such as that of Fig. 3, but as pointed out it is the fact of the presence of the maximum that, as is recognized in the invention, is useful.

5 Figs. 9 and 10 are the corresponding graphs to Figs. 3 and 5, when the feed rate of the coal is increased to 1200 kg/hr. through the mill. The size and positions of the various peaks can be seen to have altered, indicating again the potential importance of factors other than the
10 liquid content on the efficiency.

 As can be seen from Fig. 4, the graph of the electric power used by the mill also displays a maximum, in dependence on the quantity of added liquid. Again, from the experiments, the maximum power was
15 associated with the maximum cohesiveness of the mixture.

 The width of the maximum on the graph of power against added liquid content is less than the width of the maximum on the graph of fineness against added liquid content. In other words, the power peak
20 of Fig. 4 is narrower than the fineness peak of Fig. 3. Not only is the efficiency of milling to be measured in terms of the fineness of a given throughput, but it should also be measured in terms of the quantity of energy consumed in producing that degree of fineness.
25 It is recognized in the invention that because of the difference in widths of the peaks, it is worthwhile to move slightly away from the peaks: this will produce a large reduction in the amount of energy consumed, but only a small reduction in the degree of fineness produced.

The graph of Fig. 5 illustrates this effect. The graph is a derivation from Figs. 3 and 4; a point on the Fig. 5 graph was found by dividing the values at the liquid content on the Fig. 3 graph from the corresponding values from the Fig. 4 graph. A peak on this derived graph therefore represents an effective compromise between power consumption and fineness, insofar as these things depend upon the consistency of the mixture. As would be expected, from an inspection of Figs. 3 and 4, the graph of Fig. 5 has two peaks. It is preferable to set the mixture strength to that of the right hand peak of the two peaks, not only because that peak is highest (for that may not be the case for all mixtures and conditions) but also because the right hand peak is wider, and the wider the peak the more flexible the control means can be for keeping the liquid content at a value that gives the peak efficiency. Furthermore, even though the peak of Fig. 5 occurs at a mixture strength of about 50% added water throughput, it will be noted that the efficiency falls only very slowly as the water content is increased. There is an advantage in increasing the liquid content in that the grooves in the mill tend to empty themselves more easily the wetter the mixture. On the other hand, because the water may have to be dried off before the coal is fed into the boiler, or will evaporate in the boiler, the mixture should not be too wet. It was found that beyond about a 70% mixture strength, the benefits of increasing the water

content still further were not worth the expense of the extra drying difficulties, particularly as the efficiency at strengths above 70% is starting to be significantly less than that at 50%. If the grooves are
5 big, and thus especially not prone to clogging, the water content may be as low as 40%. Below that, the efficiency enters the trough on the Fig. 5 curve, and comminution becomes uneconomical. Further experiments have indicated that the corresponding range in the coal/oil
10 mixture, that gives a corresponding maximum efficiency, is the range from 30% to 60% added liquid.

As mentioned above, the mixtures tested all displayed the same characteristics of having a maximum on both the fineness and the power graphs.
15 The heights of the peaks and their positions varied however. Figs. 7 and 8 are examples that show the power and derived graphs, corresponding to Figs. 4 and 5 respectively, for the limestone/water mixture illustrated in Fig. 6.

20 The liquid and solid that make up the mixture that is to be comminuted may or may not be pre-mixed before being fed into the mill. If the solid has a powder or dust content even before comminution, as coal often has, it may be preferable to add some
25 if not all of liquid to control the dust (especially if the dust is explosive) before feeding the solid to the mill. However, the more cohesive the mixture, the more it tends to clog the conveyors and conduits, so it is usually preferable to feed dry solid and pure
30 liquid separately into the mill, and thus to let all

the mixing take place actually in the mill.

Reference has been made to the mill being in the vertical position. However, it is possible for the mill to be orientated in some other plane; horizontal
5 for example. The effects of gravity clearly are not the same in a horizontal mill as in a vertical mill. However, even a horizontally orientated mill can rely purely on gravity to cause a throughput of a mixture to traverse through the mill: a "head" of mixture may
10 be provided at the entrance end, the finished comminuted mixture being allowed to fall from the exit end. Similarly, the mill may be tipped at varying angles to provide varying gravitational effects on the throughput rate.

15 The material may actually be pumped into the mill, if appropriate, though the mixtures with which the invention is mainly concerned are often too cohesive to be pumped easily. Mixtures of coal and water, or coal and oil, may be pumped at all but the most cohesive
20 consistencies.

After the experiments have been concluded, the quantity of added liquid throughput that gives the maximum efficiency can be determined from the graphs, either in terms of the fineness of the comminuted solid,
25 or in terms of that fineness as compromised by the power

needed to produce it or in terms of whatever other
measure of efficiency is appropriate in the particular
case. After selecting the appropriate quantity of liquid
to be added in the mixture, production-scale comminution
5 can then be proceeded with, manual or automatic controls
being set up to keep the quantity constant.

Not every mixture displays a maximum when a
graph is plotted of the effect of added liquid through-
put on the comminution efficiency, and the process of the
10 invention is inappropriate for use with such mixtures.
Ores and minerals will display
such a maximum when comminuted with water or with
hydrocarbon liquids such as oil or lighter
than oil. Ceramics and metals too will display the
15 maximum.

However, many foodstuffs such as oilseeds
contain an oily liquid contained in a cellular solid
matrix, the liquid being released as soon as the cell
walls are broken by milling. These substances may not
20 display a maximum, if their inherent liquid content puts
them on what may be termed the "wet side" of a potential
maximum. In other words, a maximum might possibly be
made to appear if the mixture had liquid removed from
it rather than added to it, before comminution, but
25 that may be quite uneconomical. But if the material
is dried before comminution, or if it is frozen, then
the invention may come to be applicable, if the maximum
is displayed. Substances such as rubbers or resins tend

to be very difficult to comminute also, unless frozen beforehand.

Other substances when comminuted tend to liquidize (that is, the solid/liquid proportion changes) as comminution is carried out mainly as a result of the solid dissolving in the liquid. Some substances have to be milled with a liquid content that makes the mixture too wet to be cohesive. Some paints, for example, are in this category. Some of the pigment powders used for paints, though, may be able to be made cohesive without their properties being altered, and so can benefit from the invention.

Some substances that require comminution will dissolve in water, or in other cheap liquids (many fertilizers for instance) so that with them the invention is of no benefit. Other materials, such as cement, must be comminuted dry because their chemical nature changes when they become wet.

The nature of the liquid can have an effect on the maximum, both on the "peakiness" of the maximum, and on its position. For example, oil tends to soak into the pores of coal to a less extent than does water. Therefore, less oil need be added to the coal than water to produce the maximum. The other carbon products, such as coke, graphite, and carbon black, tend to display corresponding differences. This carbonaceous material may also be comminuted in low molecular weight alcohols such as methanol and ethanol or in any mixture of oil, water, and alcohol.

Some mixtures have rheological non-linearities, such as the tendency to become pseudoplastic, dilatant, or thixotropic, which can affect the peakiness and position of the maximum.

CLAIMS:

1. A process for comminuting a solid in a mill, comprising the step of mixing the solid with a liquid in such proportions that the mixture has a cohesive consistency:
wherein the mill includes moving channel means for positively transporting a cohesive mixture through the mill from the inlet to the outlet.
2. A process as claimed in claim 1, further comprising the steps of ascertaining by experiment on the mixture whether the efficiency of comminution varies as a function of the proportion of liquid added to the mixture; and if so, of controlling the quantity of liquid in the mixture substantially to be that quantity which produces the most efficient comminution.
3. A process as claimed in claim 2 wherein the quantity of liquid is substantially that quantity which produces the maximum percentage of comminuted solid passing a mesh of a given size.
4. A process as claimed in claim 2 wherein the quantity of liquid is substantially that quantity for which the numerical value of the fineness of the comminuted solid expressed as a percentage of the comminuted solid passing a mesh of a given size divided by the power required to operate the mill is at a maximum.

5. A process as claimed in claim 1, 2, 3 or 4, wherein the solid is coal, and the liquid is water.
6. A process as claimed in claim 1, 2, 3 or 4 wherein the solid is coal, and the liquid is oil.
7. A process as claimed in claim 1, 2, 3 or 4, wherein the solid is zinc, and the liquid is water.
8. A process as claimed in claim 1, 2, 3, or 4, wherein the solid is mica, and the liquid is water.
9. A process as claimed in claim 1, 2, 3, or 4 wherein the solid is limestone, and the liquid is water.
10. A process as claimed in claim 5, wherein the quantity of water added to the coal is substantially 40% to 70% of the mass throughput of the coal.
11. A process as claimed in claim 6, wherein the quantity of oil added to the coal is substantially 30% to 60% of the mass throughput of the coal.

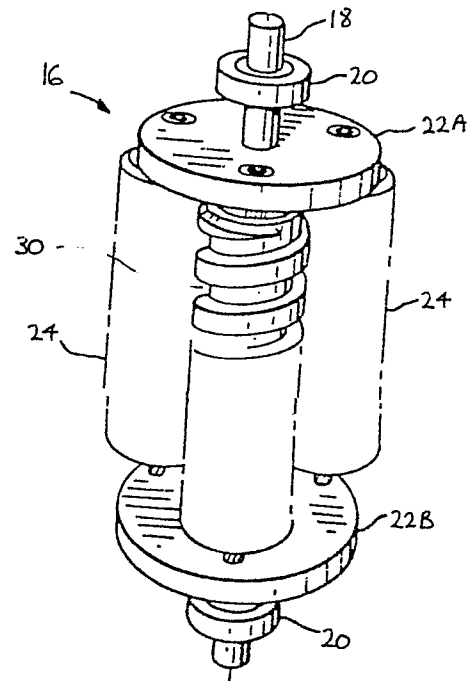


FIG. 2

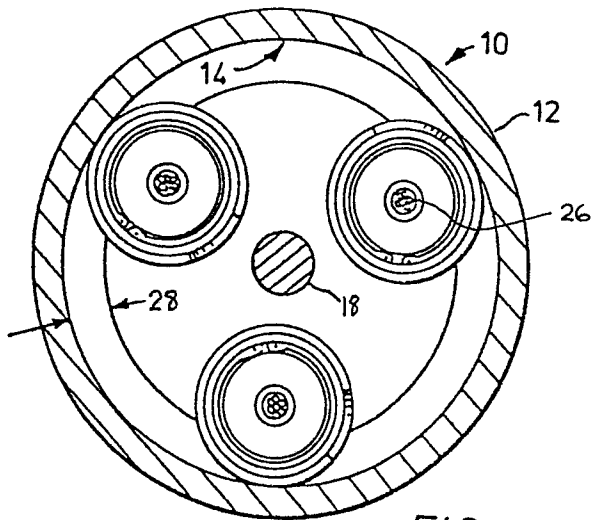
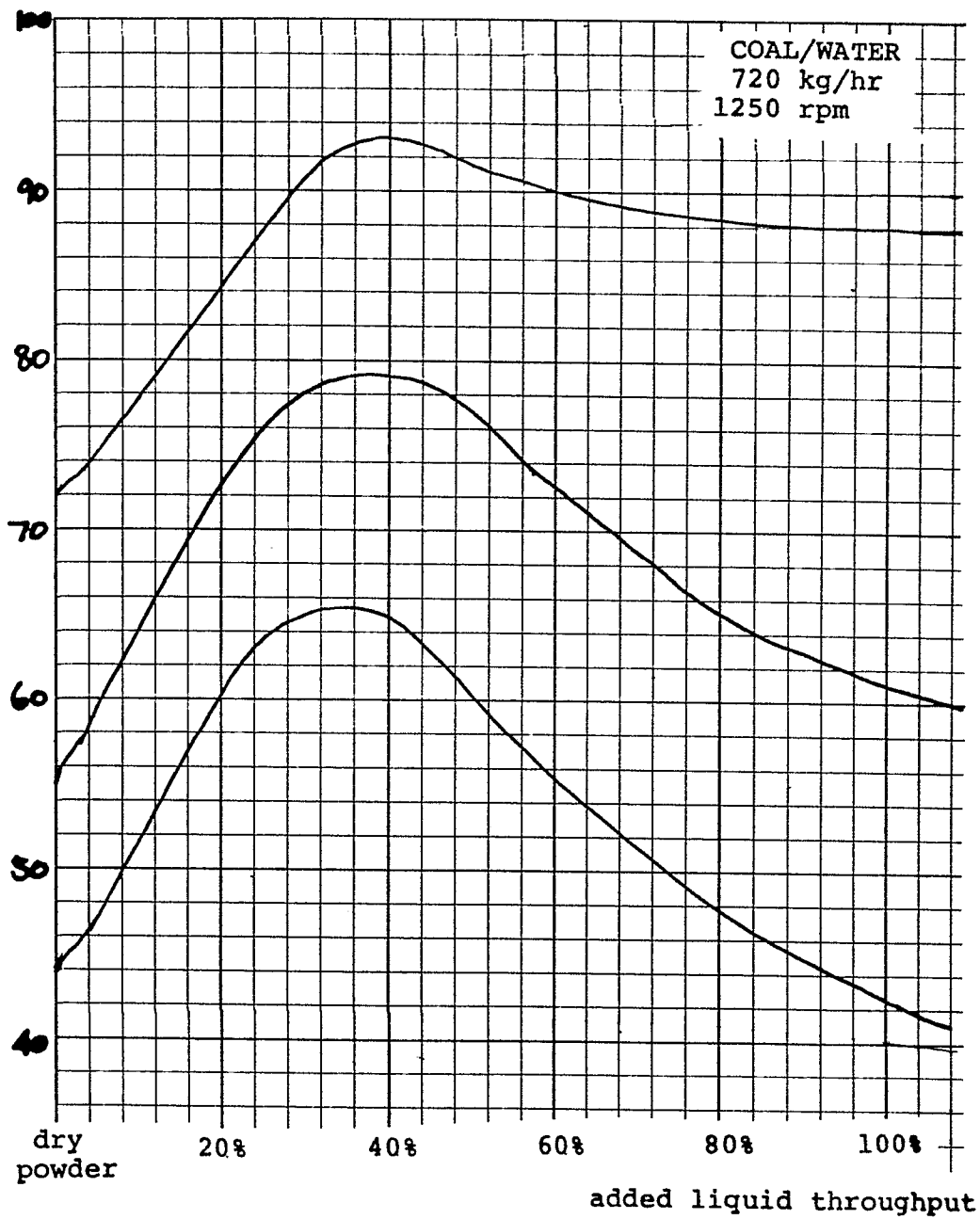


FIG. 1

FIG. 3

FINENESS (Percentage of solid throughput
passing given mesh size)



3/9

FIG. 4

MILL POWER CONSUMPTION (kw)

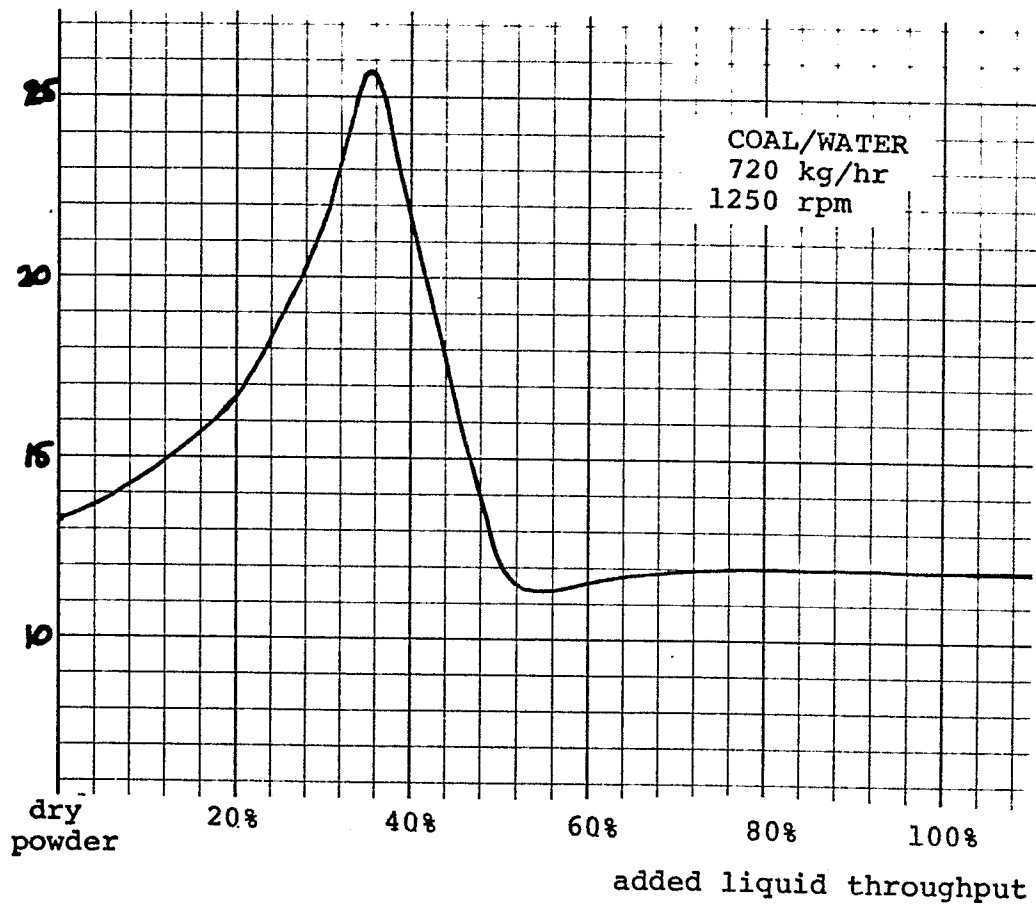
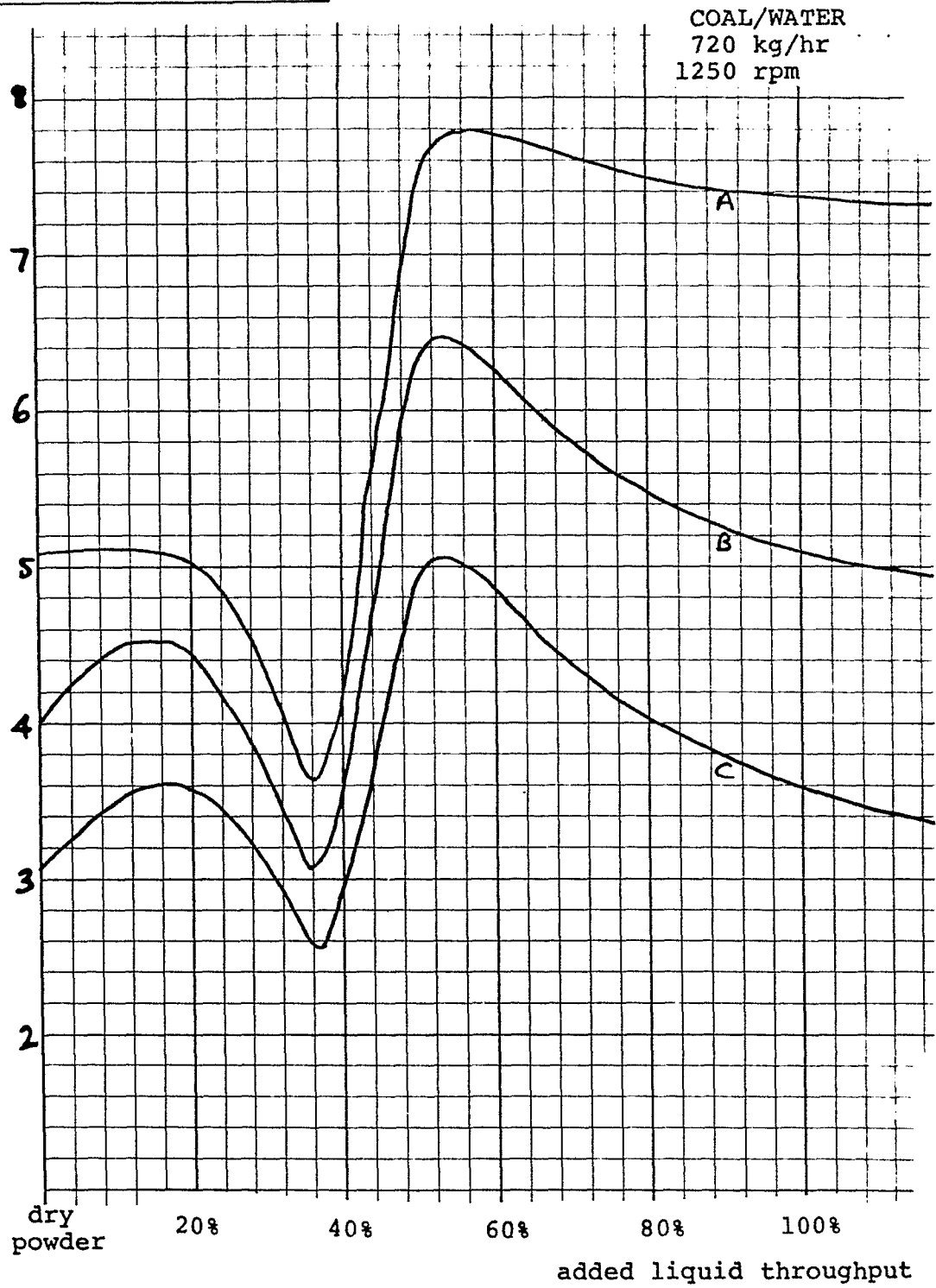


FIG. 5

COMMINUTION EFFICIENCY



5/9

FIG. 6

FINENESS (Percentage of solid throughput
passing given mesh size)

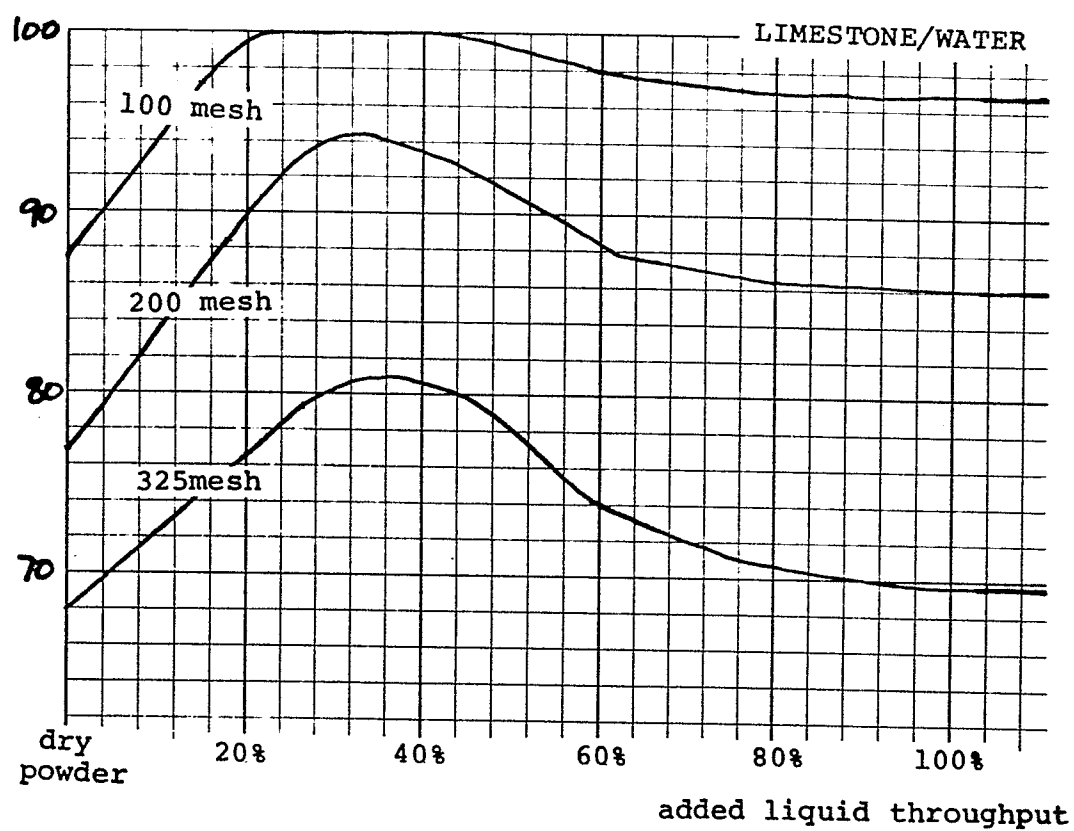
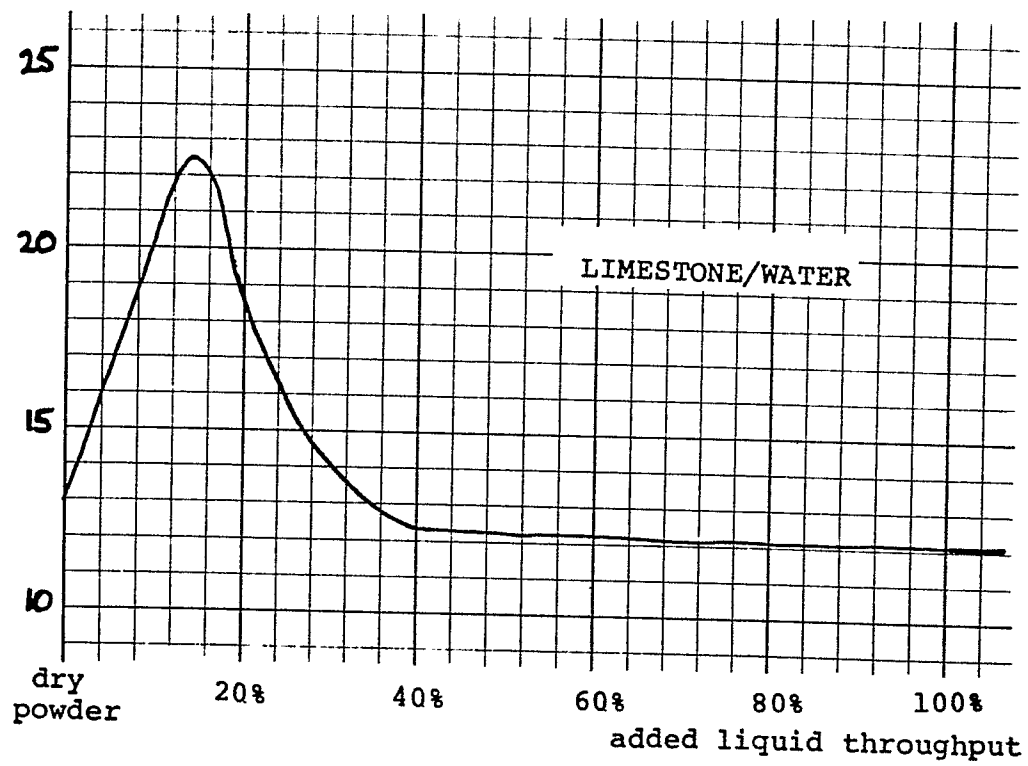


FIG. 7MILL POWER CONSUMPTION (kw)

7/9

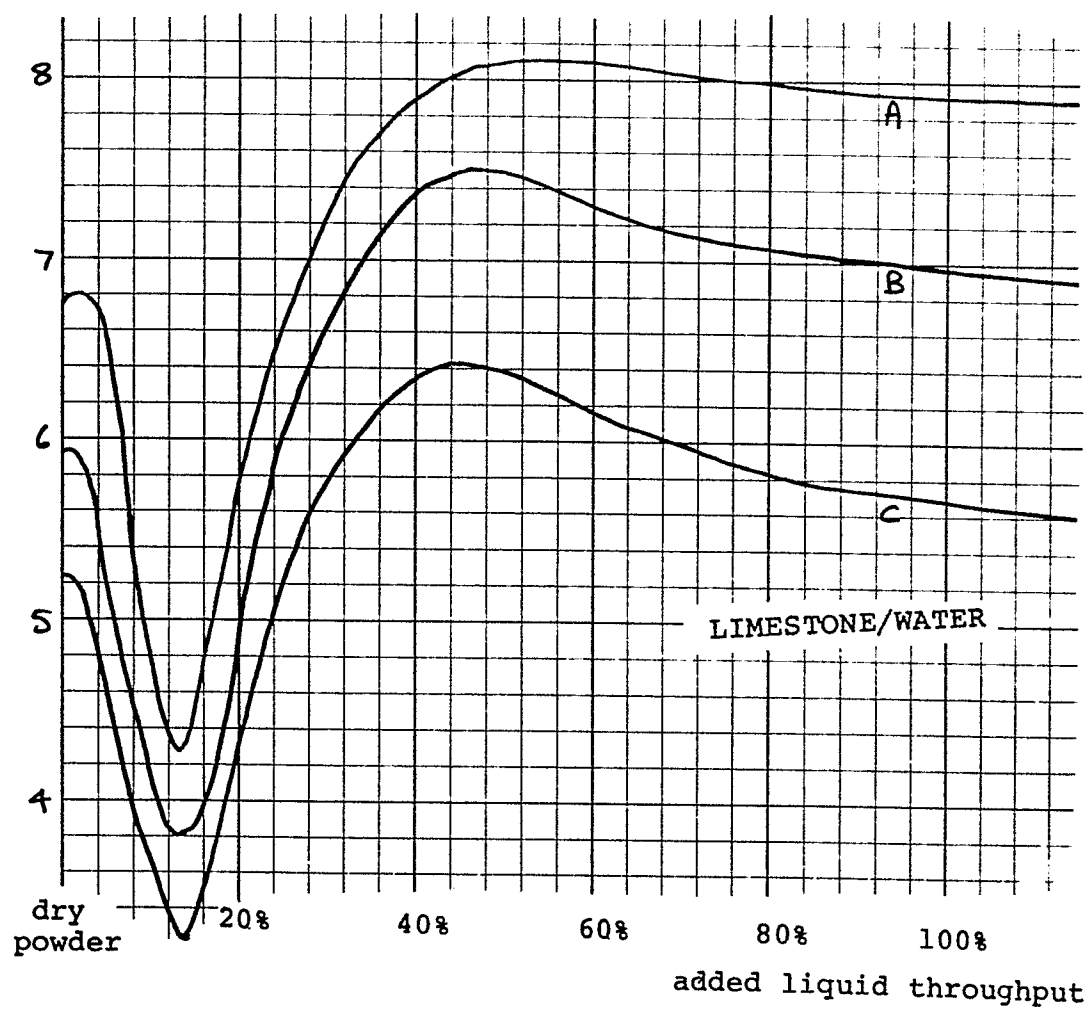
FIG. 8COMMINUTION EFFICIENCY

FIG. 9

FINENESS (Percentage of solid throughput
passing given mesh size)

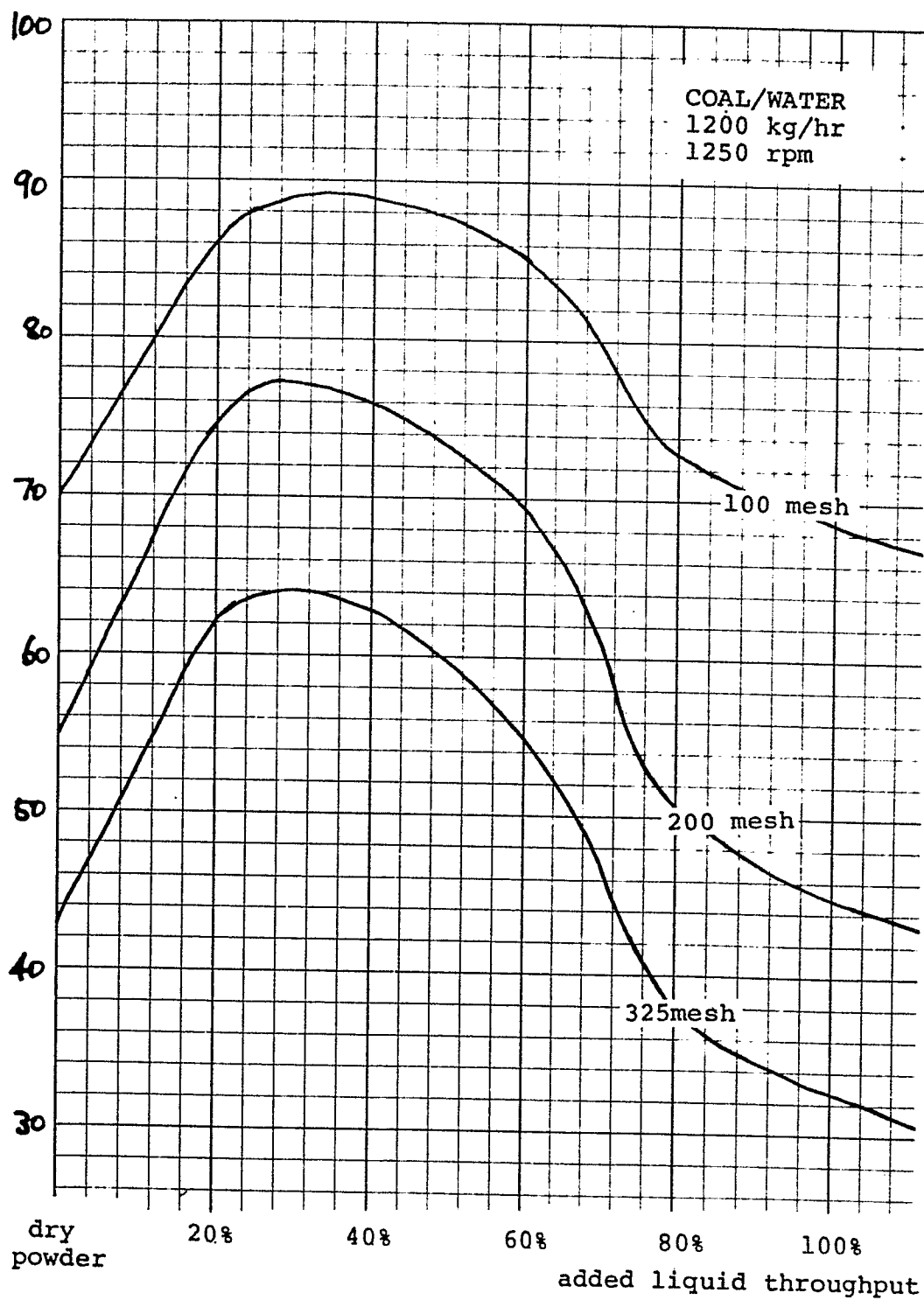


FIG. 10

COMMINUTION EFFICIENCY

