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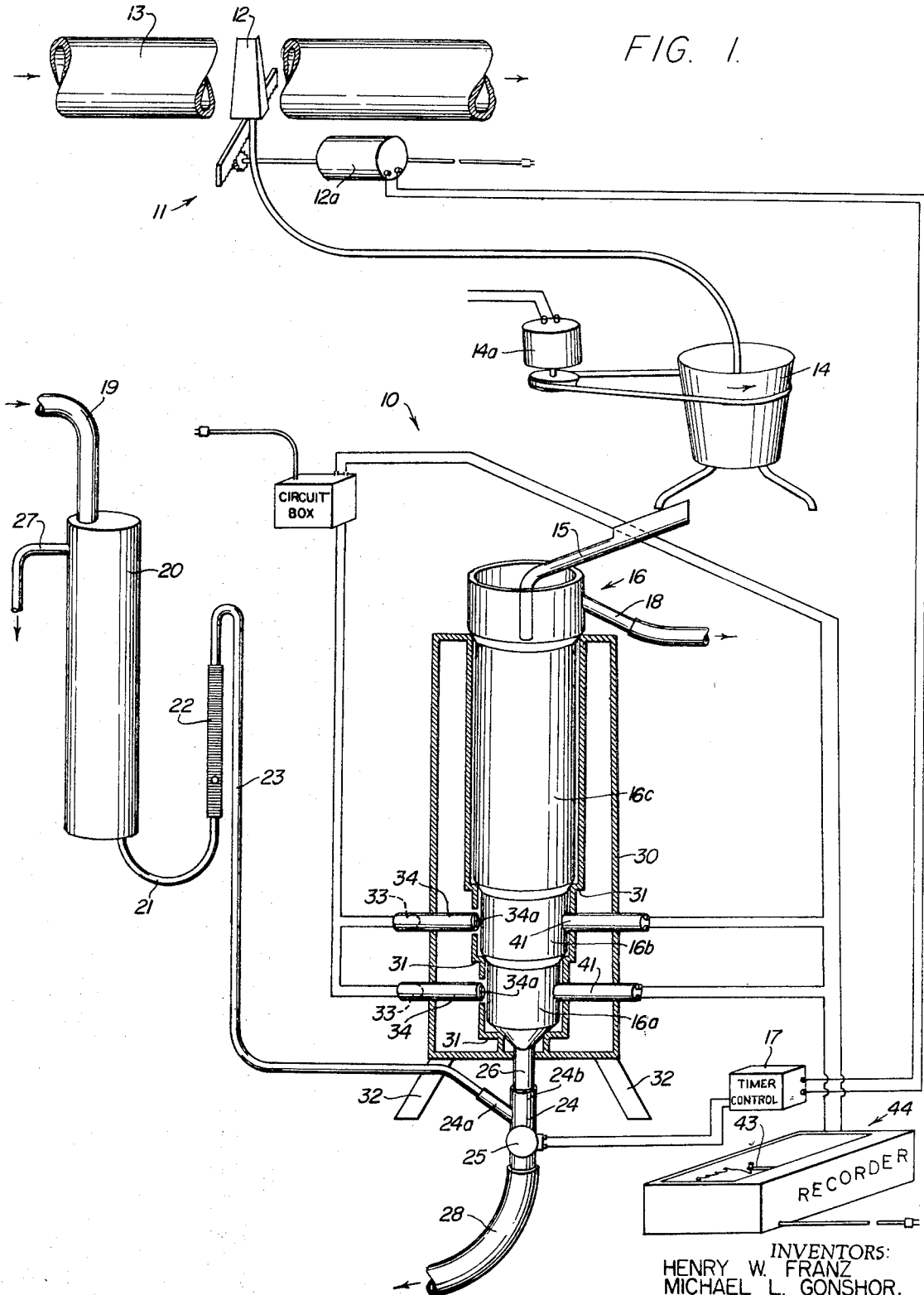
H. W. FRANZ ET AL

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METHOD AND APPARATUS FOR DETERMINING PARTICLE SIZE DISTRIBUTION
IN DISCRETE SOLIDS INCLUDING AN ELUTRIATION TUBE

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2 Sheets-Sheet 1



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ATTORNEYS

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METHOD AND APPARATUS FOR DETERMINING PARTICLE SIZE DISTRIBUTION IN DISCRETE SOLIDS INCLUDING AN ELUTRIATION TUBE

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ABSTRACT OF THE DISCLOSURE

Discrete solid particles, having different shapes, sizes, and specific gravities and constituting a sample of material such as crushed and ground ore, are allowed to seek different levels in a staged vessel through which a fluid is passed upwardly from bottom to top. Radiation, such as a light beam, is directed into the material in at least one of the stages and is sensed to obtain a measurement of the amount of radiation that actually passes through the material. This measurement is used to control a material processing or handling operation.

BRIEF SUMMARY OF THE INVENTION

This invention relates to both method and apparatus for quickly determining particle size distribution in discrete solid materials, and has particular utility in extractive metallurgy in controlling fineness of grind of ore materials being prepared for milling procedures.

In the processing of ores to recover metallic values therefrom it is usually necessary to crush and grind the ore before subjecting it to further processing. If the ore particles are not sufficiently reduced in size, an optimum amount of the mineral or minerals sought cannot be recovered, and, if the grind is too fine, the cost of handling the material becomes too great for economical production.

There is, therefore, an optimum size for the ore particles that is governed by the nature of the material being processed, the mineral or minerals to be recovered, the recovery process employed, and the economics of production. Since it is not possible to grind ore so that all particles are the same size, or are even sized within an optimum range determined according to the criteria set forth above, it is necessary to control the crushing or grinding operation or both in such a manner that a maximum percentage of the resulting ore particles are sized within the desired range.

In the past this control has usually been effected by repeatedly obtaining samples of the ore being crushed and then analyzing the sample particles. The analysis has required drying and weighing of the sample, after which it is screened, with the fractions of the sample that are retained on respective standard mesh screens of a series of such screens graduated in mesh size from very fine to very coarse being individually weighed to determine what proportion they bear to the total sample. The crushing time is then increased or decreased, as required, and repeated samples are taken and analyzed until the desired amount of the ore sample is held on the screen or screens that retain particles of the optimum sizes. This previously used analyzing method is slow and since changes in the crushing operation are desirably made on a continuing basis, without a time lag, it is not satisfactory.

It is an object of the present invention to provide a method for quickly and easily determining the relative percentages of the particles of a sample of finely divided material, such as crushed ore, that are sized within predetermined limits; without requiring the long time ordi-

narily necessary to dry, screen, and weigh samples of such material in accordance with customary practice.

Other objects are to provide apparatus for carrying out the aforesaid method rapidly and continuously on sequential ore samples, and for using the data obtained to control a crushing operation.

These objects are accomplished by the utilization of an elutriation tube whose diameter increases in steps to provide sections of varying diameter, through which a continuous, constant volume stream of a fluid, such as water, is forced upwardly at constant velocity through each section. The sample to be analyzed is dropped into the top of the tube and particles, depending on their size, are suspended in one or another or all of the sections of the tube. A vertically collimated light is directed into individual sections laterally of the tube, and light detecting apparatus is used to sense the intensity of light passing through the water and suspended particles in such sections. The sensed light is indicative of the population or number of particles suspended in the liquid between the light source and the light detector, and, by properly correlating the upward liquid flow rate with the diameters of the respective sections, the sensed particle populations can be determined and the reading for each section can be made to correspond to a standard screen reading obtained when the sample is screened and weighed.

A special feature of the invention is that the elutriation tube is specially designed to minimize effects that may be introduced by electrostatic charges, apparently contained by very fine particles and tending to move these fine particles downwardly into the lower stages of the elutriation tube where larger particles are suspended.

There is shown in the accompanying drawings a specific embodiment of the invention representing what is presently regarded as the best mode of carrying out the generic concepts in actual practice. From the detailed description of this presently preferred form of the invention, other more specific objects and features will become apparent.

The drawings:

FIG. 1 is a schematic view of the apparatus of the invention arranged to provide a signal for use in controlling a crushing operation;

FIG. 2, a diagram of the circuit for the lamps and light detectors of the particle size analyzer and the recorder; and

FIG. 3, a diagram of the circuit for controlling the sequential operation of the timer regulating sampling and feed and discharge of the samples.

DETAILED DESCRIPTION

In the illustrated preferred embodiment the particle size analyzer is designated 10 and is arranged to receive representative samples of crushed or ground ore from a sampler, shown at 11. The cutter 12 of the illustrated sampler is arranged to fully traverse the discharge path of crushed or ground and slurred ore carried by conduit 13, and, after passage of the sample through a rotating secondary sample cutter 14, at least a portion of the sample is delivered into a line 15 that is arranged to feed into the elutriation tube 16 of the particle size analyzer of the invention.

Cutters 12 and 14 are respectively driven by operation of motors 12a and 14a to periodically obtain a sample, and the motors are electrically connected to a sequence timer 17 to synchronize operation of the particle size analyzer with the operation of the sampler, in a manner to be more fully explained. With the apparatus disclosed, a wet sample of ore is obtained and is placed in the elutriation tube to be analyzed, but it should be obvious that a dry sample could as well be analyzed in the same manner. Water added with the sample is backwashed out

of the elutriation tube through an overflow spout 18, carrying with it the very fine particles, while the larger particles settle in the various stages of the tube in the same manner as do larger particles that are introduced dry. It is desirable that the line 15 extend into the elutriation tube 16 to a point below the level of the overflow spout 18 to prevent larger particles being washed out before they can settle in one of the stages of the tube.

During the analyzing operation, water is supplied to the elutriation tube from a source, not shown, through a conduit 19, a constant head tank 20, a conduit 21, a flowmeter 22, another conduit 23 and the fitting 24.

A valve 25 in the fitting 24 is controlled by the timer 17, which is actuated by operation of motor 12a, and, when the valve is closed, water is directed upwardly by way of line 26 into and through the elutriation tube and out the overflow spout 18.

The illustrated constant head tank has an overflow conduit 27, that extends outwardly from the tank at a desired height. The conduit 21 is connected to the bottom of constant head tank 20 and to the bottom of the flowmeter 22 and is smaller than the inlet conduit 19 and is incapable of carrying all of the water introduced through conduit 19, so that a continuous head of water is maintained in the constant head tank 20. The level at which the water is maintained in tank 20 is determined by the location of overflow conduit 27.

Water passing through conduit 21 goes through flowmeter 22, which may be of any conventional type but preferably one that will afford visual observation of the rate of flow therethrough. Thus, should the rate of flow through conduit 21, the flowmeter 22, and conduit 23 change during a sampling procedure, the operator will be alerted that the readings obtained may be erroneous and he will be able to take necessary corrective action.

While a particular constant head tank and a particular flowmeter are here illustrated, it should be obvious that other conventional apparatus capable of maintaining a constant volume fluid flow to the elutriation tube could as well be used.

When control valve 25 is opened, the water and suspended sample contained within tube 16 are discharged through a drain conduit 28. Because of the acute angle relationship of the branch 24a of fitting 22 to the through-pipe 24b, water from conduit 23, discharged through open valve 25 and conduit 28 does not backflow into the elutriation tube 16 to retard discharge therefrom nor does discharge from the elutriation tube backflow into conduit 23. The water and sample in the tube 16 is, therefore, freely discharged under the influence of gravity, through conduit 28. The tube 16 is fully flushed after each sampling operation, and no residue of the spent sample remains to contaminate the next sample to be analyzed.

When valve 25 is closed and water passes upwardly through the elutriation tube, it moves sequentially through a series of sections 16a, 16b, and 16c of the tube, each succeeding section having a larger inside diameter than the one below. The flow rate into the tube and through each section is constant, but in each succeeding section the rate of flow will be less than in the one preceding since the cross sectional areas are increasing.

As illustrated, the elutriation tube is glass and a vertically collimated light is arranged to be directed through the several sections. The intensity of the light transmitted by an individual section is sensed, by apparatus to be described, and is indicative of the population or number of particles suspended in that section.

While it will be obvious that other support structure can be used, there is shown in FIG. 1 a housing 30 that supports the tube 16 by means of a shoulder 31 beneath each section. The housing itself is supported by legs 32, shown fragmentarily.

A lamp 33 is provided for each of the sections 16a and 16b and each lamp is in a housing 34 that is slotted at

34a to direct the light in vertically collimated fashion through the elutriation tube. The vertical collimation of the light insures that an average light intensity reading will be obtained. The lamps are each supported by the exterior wall of housing 30. As is best seen in FIG. 2, power for the lamps is provided from a conventional 117 volt power source (not shown), through lines 36 and 37, variable transformer 38 and lines 39 and 40.

Light detectors 41 are mounted in the exterior wall of housing 30, with one detector being positioned opposite each lamp 33. As illustrated, the light detectors are cadmium sulfide cells, that create a resistance change in the circuit 42 to operate a pen 43 (FIG. 1) of a strip recorder 44.

Power is supplied to a transformer 45 of the circuit 42 from the same conventional 117 volt source (not shown) that supplies alternating current to the lamps 33, through lines 36 and 37.

Circuit 42 includes lines 46 and 47 from transformer 45, a rectifier 48 in line 46 to change the alternating current to direct current, a capacitor filter 49, a Zener diode 50, a load resistor 51 and a voltage divider 52 connected in parallel between the lines 46 and 47, and lines 53 and 54, connected to the tap 55 of voltage divider 52 and to line 47, respectively. The cadmium sulfide cells are each connected in line 53 and a resistor 56 is connected to create a voltage drop, across the lines 53 and 54 that is dependent upon the light intensity picked up by the light detectors. The voltage drop is sensed by the strip recorder to operate the pen 43. An Electronic 19 Recorder, manufactured by the Honeywell Manufacturing Co., has been found well suited for this purpose. An operator, using the recorded data, can then manually control the crushing or grinding operation as required to achieve the optimum particle size distribution. In conventional fashion, the signal used to operate pen 43 can also be used to regulate valves or other control structure in the ore flowstream to thereby recirculate the ore for further crushing or grinding or to otherwise change the crushing or grinding operation.

In operation, the lamps 33, light detectors 41, and recorder 44 are continuously functioning. The first sample introduced will normally be a standard sample, i.e. one that has been previously found to have a desired percentage of ore particles sized within the optimum range, and the overflow conduit will be positioned to set the flow rate of water through the elutriation tube, as required, until the light intensity readings obtained are representative. The light intensities can be measured through sections in which optimum sized particles are suspended or they can be taken through sections in which only larger particles accumulate, the number of larger particles being representative of the particle make-up of the sample and, therefore, of the ore being crushed. For continued operation, pulp samples are supplied to tube 16 periodically, in accordance with the programmed operation of the motor 12a that drives cutter 12. After the particles of each sample have had time to seek their level in the tube and the light intensity passed through them has been recorded the samples are discharged and the elutriation tube 16 is readied for another cycle of operation.

As shown in FIG. 3, the circuit for controlling operation of the discharge valve 25 includes lines 57 and 58 that respectively interconnect power supply lines 59 and 60 leading to the cutter motor 12 and one side of the transformer 61. The other side of transformer 61 is connected by lines 62 and 63 to the solenoid of valve 25. A manually operated switch 64 is connected to line 62 to allow for selective manual operation of dump valve 25, and a by-pass line 65 around switch 64 includes a switch 66 that is adapted to be closed and to be briefly held closed by the cam 84 driven by timer motor 17.

Another pair of lines 68 and 69 are respectively connected to lines 59 and 60, between switches 70 and 71

that are positioned in the lines to control operation of the sample cutter and the cutter motor 12a. Thus, as the switches 70 and 71 are closed by a timer cam 12b to briefly operate cutter motor 12a, i.e. for 3-5 seconds, a circuit is completed through the lines 68 and 69 and a coil 72 of a relay 73. This closes contact 74 of the relay and momentarily completes a circuit through line 75 that is connected to line 62 and the line 76, which is connected through a coil 77 of a relay 78 to line 63.

Energization of coil 77 closes contacts 79 and 80 of the relay 78 to complete circuits from line 62, through line 81, contact 80, timer motor 17 and line 63, and from line 62, through normally closed switch 82, line 83, contact 80, line 76, coil 77, and line 63, to maintain the coil 77 energized and the contacts 79 and 80 closed even after cutter head 12 has traversed flow stream 13 and switches 70 and 71 have opened to break the current to motor 12a.

As the timer motor 17 begins to operate, cams 84 and 85 driven thereby respectively and sequentially close switch 86 and open switch 82. Opening of switch 82 breaks the holding circuit through the coil 77 and allows contacts 79 and 80 to open. However, the time motor will continue to run for a period of time predetermined by cam 84, which holds switch 86 closed to complete a circuit through lines 62 and 88, the switch 86, timer motor 17, and lines 89 and 63.

Shortly before cam 84 releases switch 86 to break the circuit to timer motor 17 the switch 66 is closed by the cam 84.

Closing of switch 66 completes a circuit through lines 62 and 65, the switch 66, the solenoid of dump valve 25, and line 63. Energization of the solenoid opens valve 25 to allow the water and sample therein to be discharged from tube 15.

Immediately before cam 84 moves to allow switches 66 and 86 to assume their normally open condition, wherein valve 25 closes and water is again directed upwardly through tube 16, cam 85 returns the switch 82 to its normally closed position. When switches 66 and 86 are open, the circuit through timer motor 17 is broken and the circuit is ready for another cycle of operation.

It has been observed in general that ore particles are suspended in the sections of the elutriation tube in accordance with their shapes, sizes and specific gravities. It has been found that the factors of shape and specific gravity have little effect since a very large proportion of any ore will be made up of minerals having substantially the same density. For example, quartz, feldspars and calcites have densities very close to 2.7 and these materials normally make-up the bulk of the ore sampled. The more dense minerals make up only 3-8 percent of the ore, and, even though the smaller particles of these materials may migrate to lower sections of the elutriation tube, their volume does not significantly affect the readings obtained. Thus, with proper control of the volume of water flowed upwardly through the elutriation tube, an effective determination can be made of the size of the ore particles sampled.

Very fine particles, i.e. those that will pass a 100 mesh screen and that are not carried up and out through the overflow spout, do not all remain in the upper section of the tube 16, as might be expected. Instead, apparently because of an electrostatic charge picked up by these particles, some of them tend to migrate downwardly into the lower sections.

The effect introduced into data obtained by determining the light intensities passed through the lower sections into which some of the very fine particles have migrated is preferably minimized by elongating the upper section 16c, as shown in FIG. 1. The readings then obtained are more sensitive than can be obtained without correction for the migrating effect.

When the upper section is elongated, the small particles migrate downwardly therein; but only a small propor-

tion of the particles continue the migration into the lower, reduced sections, and these particles are not so populous as to significantly affect the light intensity readings obtained through these lower sections.

In a particular instance, wherein the ore being sampled had an overall specific gravity of about 2.7, water was supplied from the constant head tank 20 to the elutriation tube 16 at a flow rate of 1640 milliliters per minute. The inside diameters of the lowermost, intermediate and upper sections of the tube were 1.9 centimeters, 2.9 centimeters, and 4.1 centimeters, respectively, and the upper section was approximately 4.3 times as long as the other sections. The various sections were quickly stoppered, and analysis by drying, weighing and screening showed that the fine particles were not present in the lower sections in quantities great enough to significantly affect the light intensity readings.

While here described as being particularly useful in determining the size distribution of ore particles, as a means of controlling a crushing operation, it should be obvious that the method of the invention and the analyzing apparatus can as well be used in other operations, where it is necessary to determine the make-up of a material in terms of its particle sizes.

Where this invention is here described and illustrated with respect to certain forms thereof, it is to be understood that many variations are possible without departing from the subject material particularly pointed out in the following claims which subject matter we regard as our invention.

We claim:

1. A method of determining particle size distribution in discrete solids, which method comprises

establishing a constant velocity, upward flow of fluid through a vessel having stages that increase in cross-sectional area from bottom to top of the vessel;

directing radiation laterally into a plurality of said stages for travel thereacross;

feeding a test sample of said discrete solids into the vessel at or near the top thereof, so that discrete solid particles migrate downwardly in the vessel against the upward flow of fluid, and particles of different sizes seek different levels in the vessel; and when said particles are substantially suspended at said different levels, sensing the amount of radiation that passes through the material in respective stages into which radiation is directed.

2. A method according to claim 1, further comprising regulating the flow rate of the fluid passing through the vessel so as to maintain, in respective stages into which radiation is directed, particles of sizes that would be retained on screens of selected standard mesh sizes.

3. A method according to claim 1, further comprising correlating measurements of the sensed radiation from the respective stages with similar measurements from the same stages when a reference sample of known particle-size distribution is substantially suspended in the vessel.

4. A method according to claim 3, further comprising controlling a processing operation, having a relation to the material from which the test sample was taken, in accordance with the deviation of each measurement of the sensed radiation from the test sample with the corresponding measurement of the sensed radiation from the reference sample.

5. A method according to claim 4, wherein the material from which the test sample was taken is crushed and ground ore, and wherein the controlled processing operation is size-reduction of said ore.

6. A method according to claim 5, wherein the crushed and ground ore is sampled periodically; the samples are passed, respectively, to the vessel in sequence; and each test sample is discharged from the vessel before the next test sample is introduced.

7. A method according to claim 1, wherein the uppermost stage is deeper than any of the other stages and

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is employed to remove fines from the sample and not for sensing particle population.

8. Apparatus for determining particle size distribution in discrete solids, comprising

a vessel having successive stages that increase in cross-sectional area from bottom to top of said vessel; sources of radiation arranged to direct radiant energy across respective stages of a plurality of said stages; radiation detectors arranged to sense radiant energy that passes through the material in the respective stages;

means for continuously introducing a fluid into the vessel at or near its bottom at a substantially uniform rate;

overflow means at or near the upper end of the vessel; and

means for introducing discrete solid material into the vessel at or near its top.

9. Apparatus according to claim 8, further including measurement means; and means for operating said measurement means to indicate the amount of radiation sensed by the radiation detector for respective stages.

10. Apparatus according to claim 8, wherein the sources of radiation are lights and the radiation detectors are respective light sensing means, and wherein there are additionally included means for vertically collimating

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the light radiated from the light source and received by the light sensing means.

11. Apparatus according to claim 8, wherein there are additionally provided means for periodically taking representative samples from a stream of ore pulp; means for successively introducing said samples into the vessel at or near its top; and means for periodically discharging material from the vessel.

12. Apparatus according to claim 8, wherein an upper stage of the vessel is deeper than the stages therebeneath to entrap very fine particles in said upper stage.

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