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(54) Title: OPTIMIZED BITUMEN RECOVERY AND PROCESS AID DOSAGE VIA WATER CHEMISTRY FEEDBACK
CONTROL

(57) Abrégé/Abstract:

A method comprising:

- a) providing an oil sand slurry stream;
- b) adding a process aid to the oil sand slurry stream;
- c) processing the oil sand slurry stream into bitumen froth, fine tailings (FT), and coarse sand tailings (CST), including using a primary separation cell (PSC);
- d) measuring a water chemistry parameter of at least one of the oil sand slurry stream, the FT, the CST, the bitumen froth, middlings from the PSC, and a middling layer inside the PSC; and
- e) based on the measured water chemistry parameter, adjusting at least one of a dosage of the process aid added to the oil sand slurry stream, process temperature, mixing conditions, oil sand slurry stream composition, and water addition to the PSC.

ABSTRACT

A method comprising:

- a) providing an oil sand slurry stream;
- b) adding a process aid to the oil sand slurry stream;
- c) processing the oil sand slurry stream into bitumen froth, fine tailings (FT), and coarse sand tailings (CST), including using a primary separation cell (PSC);
- d) measuring a water chemistry parameter of at least one of the oil sand slurry stream, the FT, the CST, the bitumen froth, middlings from the PSC, and a middling layer inside the PSC; and
- e) based on the measured water chemistry parameter, adjusting at least one of a dosage of the process aid added to the oil sand slurry stream, process temperature, mixing conditions, oil sand slurry stream composition, and water addition to the PSC.

OPTIMIZED BITUMEN RECOVERY AND PROCESS AID DOSAGE VIA WATER CHEMISTRY FEEDBACK CONTROL

BACKGROUND

Field of Disclosure

[0001] The disclosure relates generally to the field of oil sand processing, and more particularly to water-based extraction.

Description of Related Art

[0002] This section is intended to introduce various aspects of the art, which may be associated with the present disclosure. This discussion is believed to assist in providing a framework to facilitate a better understanding of particular aspects of the present disclosure. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

[0003] Modern society is greatly dependent on the use of hydrocarbon resources for fuels and chemical feedstocks. Hydrocarbons are generally found in subsurface formations that can be termed “reservoirs”. Removing hydrocarbons from the reservoirs depends on numerous physical properties of the subsurface formations, such as the permeability of the rock containing the hydrocarbons, the ability of the hydrocarbons to flow through the subsurface formations, and the proportion of hydrocarbons present, among other things. Easily harvested sources of hydrocarbons are dwindling, leaving less accessible sources to satisfy future energy needs. As the costs of hydrocarbons increase, the less accessible sources become more economically attractive.

[0004] Recently, the harvesting of oil sand to remove heavy oil has become more economical. Hydrocarbon removal from oil sand may be performed by several techniques. For example, a well can be drilled to an oil sand reservoir and steam, hot air, solvents, or a combination thereof, can be injected to release the hydrocarbons. The released hydrocarbons may be collected by wells and brought to the surface. In another technique, strip or surface

mining may be performed to access the oil sand, which can be treated with water, steam or solvents to extract the heavy oil.

[0005] Oil sand extraction processes are used to liberate and separate bitumen from oil sand so that the bitumen can be further processed to produce synthetic crude oil or mixed with diluent to form “dilbit” and be transported to a refinery plant. Numerous oil sand extraction processes have been developed and commercialized, many of which involve the use of water as a processing medium. Where the oil sand is treated with water, the technique may be referred to as water-based extraction (WBE) or as a water-based oil sand extraction process. WBE is a commonly used process to extract bitumen from mined oil sand.

[0006] One WBE process is the Clark hot water extraction process (the “Clark Process”). This process typically requires that mined oil sand be conditioned for extraction by being crushed to a desired lump size and then combined with hot water and perhaps other agents to form a conditioned slurry of water and crushed oil sand. In the Clark Process, an amount of sodium hydroxide (caustic) may be added to the slurry to increase the slurry pH, which enhances the liberation and separation of bitumen from the oil sand. Other WBE processes may use other temperatures and may include other conditioning agents, which are added to the oil sand slurry, or may operate without conditioning agents. This slurry is first processed in a Primary Separation Cell (PSC), also known as a Primary Separation Vessel (PSV), to extract the bitumen from the slurry.

[0007] In one WBE process, a water and oil sand slurry is separated into three major streams in the PSC: bitumen froth, middlings, and a PSC underflow (also referred to as coarse sand tailings (CST)).

[0008] Regardless of the type of WBE process employed, the process will typically result in the production of a bitumen froth that requires treatment with a solvent. For example, in the Clark Process, a bitumen froth stream comprises bitumen, solids, and water. Certain processes use naphtha to dilute bitumen froth before separating the product bitumen by centrifugation. These processes are called naphtha froth treatment (NFT) processes. Other

processes use a paraffinic solvent, and are called paraffinic froth treatment (PFT) processes, to produce pipelineable bitumen with low levels of solids and water. In the PFT process, a paraffinic solvent (for example, a mixture of iso-pentane and n-pentane) is used to dilute the froth before separating the product, diluted bitumen, by gravity. A portion of the asphaltenes in the bitumen is also rejected by design in the PFT process and this rejection is used to achieve reduced solids and water levels. In both the NFT and the PFT processes, the diluted tailings (comprising water, solids and some hydrocarbon) are separated from the diluted product bitumen.

[0009] Solvent is typically recovered from the diluted product bitumen component before the bitumen is delivered to a refining facility for further processing.

[0010] The PFT process may comprise at least three units: Froth Separation Unit (FSU), Solvent Recovery Unit (SRU) and Tailings Solvent Recovery Unit (TSRU). Mixing of the solvent with the feed bitumen froth may be carried out counter-currently in two stages in separate froth separation units. The bitumen froth comprises bitumen, water, and solids. A typical composition of bitumen froth is about 60 wt. % bitumen, 30 wt. % water, and 10 wt. % solids. The paraffinic solvent is used to dilute the froth before separating the product bitumen by gravity. The foregoing is only an example of a PFT process and the values are provided by way of example only. An example of a PFT process is described in Canadian Patent No. 2,587,166 to Sury.

[0011] From the PSC, the middlings, which may comprise bitumen and about 10-30 wt. % solids, or about 20-25 wt. % solids, based on the total wt. % of the middlings, is withdrawn and sent to the flotation cells to further recover bitumen. The middlings are processed by bubbling air through the slurry and creating a bitumen froth, which is recycled back to the PSC. Fine tailings (FT) from the flotation cells, comprising mostly solids and water, are sent for further treatment or disposed in an external tailings area (ETA).

[0012] It would be desirable to have an alternative or improved method of water-based oil sand extraction.

SUMMARY

[0013] It is an object of the present disclosure to provide an alternative method of water-based oil sand extraction.

[0014] Disclosed is a method of comprising:

- a) providing an oil sand slurry stream;
- b) adding a process aid to the oil sand slurry stream;
- c) processing the oil sand slurry stream into bitumen froth, fine tailings (FT), and coarse sand tailings (CST), including using a primary separation cell (PSC);
- d) measuring a water chemistry parameter of at least one of the oil sand slurry stream, the FT, the CST, the bitumen froth, middlings from the PSC, and a middling layer inside the PSC; and
- e) based on the measured water chemistry parameter, adjusting at least one of a dosage of the process aid added to the oil sand slurry stream, process temperature, mixing conditions, oil sand slurry stream composition, and water addition to the PSC.

[0015] The foregoing has broadly outlined the features of the present disclosure so that the detailed description that follows may be better understood. Additional features will also be described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] These and other features, aspects and advantages of the disclosure will become apparent from the following description, appending claims and the accompanying drawings, which are briefly described below.

[0017] Fig. 1 is a graph of the effects of caustic on primary bitumen recovery at varying ore fines content.

[0018] Fig. 2 is a graph of the effects of pH on primary bitumen recovery at varying ore fines content.

[0019] Fig 3 is a graph of the effects of caustic on tailings Na^+ concentration at varying ore fines content.

[0020] Fig. 4 is a graph of the relationship of Na/Na_0 to bitumen recovery at varying ore fines content, where Na_0 represents an initial value in process water prior contact with the ore.

[0021] Fig. 5 is a graph of the effects of caustic on tailings electrical conductivity (EC) at varying ore fines content.

[0022] Fig. 6 is a graph of the relationship of EC/EC_0 to bitumen recovery at varying ore fines content, where EC_0 represents an initial value in process water prior contact with the ore.

[0023] Fig. 7 is a graph of the effects of caustic on tailings Ca^{++} concentration at varying ore fines content.

[0024] Fig. 8 is a graph of relationship of Ca/Ca_0 to bitumen recovery at varying ore fines content, where Ca_0 represents the initial value in process water prior contact with the ore.

[0025] Fig. 9 is a graph of the effects of caustic on tailings Mg^{++} concentration at varying ore fines content.

[0026] Fig. 10 is a graph of the relationship of Mg/Mg_0 to bitumen recovery at varying ore fines content, where Mg_0 represents the initial value in process water prior contact with the ore.

[0027] Fig. 11 is a graph of the effects of caustic on tailings K^+ concentration at varying ore fines content.

[0028] Fig. 12 is a graph of the relationship of K/K_0 to bitumen recovery at varying ore fines content, where K_0 represents the initial value in process water prior contact with the ore.

[0029] Fig. 13 is a schematic of a method including adjusting process aid dosage based on a measured water chemistry parameter.

[0030] Fig. 14 is a schematic of a method including adjusting ore tonnage based on a measured water chemistry parameter.

[0031] Fig. 15 is a schematic of a method including adjusting water and/or water: ore ratio based on a measured water chemistry parameter.

[0032] It should be noted that the figures are merely examples and no limitations on the scope of the present disclosure are intended thereby. Further, the figures are generally not drawn to scale, but are drafted for purposes of convenience and clarity in illustrating various aspects of the disclosure.

DETAILED DESCRIPTION

[0033] For the purpose of promoting an understanding of the principles of the disclosure, reference will now be made to the features illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended. Any alterations and further modifications, and any further applications of the principles of the disclosure as described herein are contemplated as would normally occur to one skilled in the art to which the disclosure relates. It will be apparent to those skilled in the relevant art that some features that are not relevant to the present disclosure may not be shown in the drawings for the sake of clarity.

[0034] At the outset, for ease of reference, certain terms used in this application and their meaning as used in this context are set forth below. To the extent a term used herein is not defined below, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Further, the present processes are not limited by the usage of the terms shown below, as all equivalents, synonyms,

new developments and terms or processes that serve the same or a similar purpose are considered to be within the scope of the present disclosure.

[0035] Throughout this disclosure, where a range is used, any number between or inclusive of the range is implied.

[0036] A “hydrocarbon” is an organic compound that primarily includes the elements of hydrogen and carbon, although nitrogen, sulfur, oxygen, metals, or any number of other elements may be present in small amounts. Hydrocarbons generally refer to components found in heavy oil or in oil sand. However, the techniques described are not limited to heavy oils but may also be used with any number of other reservoirs to improve gravity drainage of liquids. Hydrocarbon compounds may be aliphatic or aromatic, and may be straight chained, branched, or partially or fully cyclic.

[0037] “Bitumen” is a naturally occurring heavy oil material. Generally, it is the hydrocarbon component found in oil sand. Bitumen can vary in composition depending upon the degree of loss of more volatile components. It can vary from a very viscous, tar-like, semi-solid material to solid forms. The hydrocarbon types found in bitumen can include aliphatics, aromatics, resins, and asphaltenes. A typical bitumen might be composed of:

- 19 weight (wt.) % aliphatics (which can range from 5 wt. % - 30 wt. %, or higher);
- 19 wt. % asphaltenes (which can range from 5 wt. % - 30 wt. %, or higher);
- 30 wt. % aromatics (which can range from 15 wt. % - 50 wt. %, or higher);
- 32 wt. % resins (which can range from 15 wt. % - 50 wt. %, or higher); and
- some amount of sulfur (which can range in excess of 7 wt. %), the weight % based upon total weight of the bitumen.

In addition, bitumen can contain some water and nitrogen compounds ranging from less than 0.4 wt. % to in excess of 0.7 wt. %. The percentage of the hydrocarbon found in bitumen can vary. The term “heavy oil” includes bitumen as well as lighter materials that may be found in a sand or carbonate reservoir.

[0038] “Heavy oil” includes oils which are classified by the American Petroleum Institute (“API”), as heavy oils, extra heavy oils, or bitumens. The term “heavy oil” includes bitumen. Heavy oil may have a viscosity of about 1,000 centipoise (cP) or more, 10,000 cP or more, 100,000 cP or more, or 1,000,000 cP or more. In general, a heavy oil has an API gravity between 22.3° API (density of 920 kilograms per meter cubed (kg/m^3) or 0.920 grams per centimeter cubed (g/cm^3)) and 10.0° API (density of 1,000 kg/m^3 or 1 g/cm^3). An extra heavy oil, in general, has an API gravity of less than 10.0° API (density greater than 1,000 kg/m^3 or 1 g/cm^3). For example, a source of heavy oil includes oil sand or bituminous sand, which is a combination of clay, sand, water and bitumen.

[0039] “Fine particles” or “fines” are generally defined as those solids having a size of less than 44 microns (μm), as determined by laser diffraction particle size measurement.

[0040] “Coarse particles” are generally defined as those solids having a size of greater than 44 microns (μm).

[0041] The term “solvent” as used in the present disclosure should be understood to mean either a single solvent, or a combination of solvents.

[0042] The terms “approximately,” “about,” “substantially,” and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numeral ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and are considered to be within the scope of the disclosure.

[0043] The articles “the”, “a” and “an” are not necessarily limited to mean only one, but rather are inclusive and open ended so as to include, optionally, multiple such elements.

[0044] The term “paraffinic solvent” (also known as aliphatic) as used herein means solvents comprising normal paraffins, isoparaffins or blends thereof in amounts greater than 50 wt. %. Presence of other components such as olefins, aromatics or naphthenes may counteract the function of the paraffinic solvent and hence may be present in an amount of only 1 to 20 wt. % combined, for instance no more than 3 wt. %. The paraffinic solvent may be a C₄ to C₂₀ or C₄ to C₆ paraffinic hydrocarbon solvent or a combination of iso and normal components thereof. The paraffinic solvent may comprise pentane, iso-pentane, or a combination thereof. The paraffinic solvent may comprise about 60 wt. % pentane and about 40 wt. % iso-pentane, with none or less than 20 wt. % of the counteracting components referred above.

[0045] Process aids (PA) are commonly used in oil sand extraction to increase bitumen recovery. PA addition to oil sand slurries has several effects on the slurry water chemistry, including changes in pH, electrical conductivity, and ions concentration. Typically, bitumen recovery increases with PA dosage up to an optimum level. Beyond this optimum level, further PA addition (over-dosage) may be detrimental to bitumen extraction. Thus, proper PA dosage is useful not only to reduce PA consumption and costs, but also to assist bitumen recovery.

[0046] Caustic dosage optimization based on ore fines wt. % (solids basis) may be known. However, experimental work herein demonstrates that the measurement of ore fines is not sufficient to predict optimum PA dosage for maximum bitumen recovery. The present invention takes into consideration water chemistry for PA dosage control or other process adjustments in a water-based oil sand extraction process.

[0047] Fig. 1 is a graph of primary bitumen recovery versus caustic at varying ore fines contents. In Fig. 1, HF (high fines) represents greater than 18 wt.% fines, LF (low fines) represents less than 10 wt. % fines, and BC (base case) represents about 11-15 wt. % fines, all on a dry bitumen basis. However, the present inventors have found that a stronger correlation exists for primary bitumen recovery versus pH as illustrated in Fig. 2, which uses the same ore labels as Fig. 1.

[0048] Surfactant release from the bitumen (responsible for bitumen-sand separation) is pH dependent. A certain pH threshold is required for maximize bitumen recovery (Fig 2b). This threshold value (a pH of about 8.6) appears to be independent of ore fines wt %. However, higher fines ores may require more caustic to reach such pH level. It has been discovered that not only does caustic dosage and ore fine content affect tailing PH, but also that other factors affecting water chemistry also affect tailings pH and maximization of bitumen recovery.

[0049] Once the ore is in contact with hot process water and PA, the process water experiences several changes. Figures 3-12 demonstrate changes in water chemistry characteristics (ions concentration and electrical conductivity) with caustic dosage. As bitumen recovery increases, Ca^{++} , Mg^{++} and K^{+} ions concentration decreases, while Na^{+} concentration and electrical conductivity (EC) increases. Table 1 provides the water characteristics of the process water prior to contact with the ore.

[0050] Table 1.

Water chemistry analysis	Units	Process water chemistry
pH	N/A	8.4
Electrical Conductivity	uS/cm	562.0
HCO ₃ ⁻	ppm, wt/vol	250.0
F ⁻	ppm, wt/vol	1.0
Cl ⁻	ppm, wt/vol	10.0
SO ₄ ⁻⁻	ppm, wt/vol	74.0
Al (396.152 nm)-Rad	ppm, wt/vol	0.6
Ba (455.403 nm)-Ax	ppm, wt/vol	0.1
Ca (422.673 nm)-Rad	ppm, wt/vol	28.0
Ca (317.933 nm)-Ax	ppm, wt/vol	27.9
Fe (259.410 nm)-Ax	ppm, wt/vol	0.1
K (766.491 nm)-Rad	ppm, wt/vol	5.9
Mg (285.213 nm)-Rad	ppm, wt/vol	11.3
Mn (257.610 nm)-Ax	ppm, wt/vol	ND
Mo (202.032 nm)-Ax	ppm, wt/vol	0.0
Na (589.592 nm)-Rad	ppm, wt/vol	89.0
Ni (216.555 nm)-Ax	ppm, wt/vol	ND
Si (288.158 nm)-Rad	ppm, wt/vol	7.0
Sr (407.771 nm)-Ax	ppm, wt/vol	0.3
Zn (213.857 nm)-Rad	ppm, wt/vol	ND

[0051] A method may comprise:

- a) providing an oil sand slurry stream comprising bitumen, water, and solids;
- b) adding a process aid to the oil sand slurry stream;

- c) processing the oil sand slurry stream into bitumen froth, fine tailings (FT), and coarse sand tailings (CST), including using a primary separation cell (PSC);
- d) measuring a water chemistry parameter of at least one of the oil sand slurry stream, the FT, the CST, the bitumen froth, middlings from the PSC, and a middling layer inside the PSC; and
- e) based on the measured water chemistry parameter, adjusting at least one of a dosage of the process aid added to the oil sand slurry stream, process temperature, mixing conditions, oil sand slurry stream composition, and water addition to the PSC.

[0052] The oil sand slurry stream may be any suitable oil sand slurry stream and may stem from mined oil sand. The oil sand slurry stream may be a feed stream to a PSC. The oil sand slurry stream may comprise 7 to 16 wt. % bitumen, 1 to 7 wt. % water, and 77 to 92 wt. % solids. The oil sand slurry stream may comprise 10 to 12.5 wt. % bitumen, 2.5 to 6 wt. % water, and 81.5 to 87.5 wt. % solids.

[0053] The process aid may be any suitable process aid and may be caustic. The process aid may be suitable to increase the pH of the slurry water.

[0054] In a PSC, bitumen froth is separated from the majority of water and solids. A feed to the PSC comprises bitumen, solids, and water, which may be an aerated oil sand slurry from a hydrotransport line stemming from mined oil sand ore. A PSC may comprise a cylindrical section at the top where aerated bitumen froth with some solids and water rises upwards and flows to the next process equipment for cleanup in froth treatment, and a conical section below, which creates a densification zone (comprising the majority of solids and water) establishing a vertical density gradient in the PSC, which enables separation of bitumen froth. The cylindrical section may comprise a froth layer, an underwash layer into which an underwash is added, and a middlings layer. The “middling layer” inside the PSC means the phase in the PSC beneath the bitumen froth and above the CST. Three streams typically leave the PSC, namely, a bitumen froth comprising the majority of the bitumen from the oil sand which is withdrawn near the top of the PSC, middlings comprising some bitumen which is

withdrawn near the bottom of the cylindrical section of the PSC and which are sent to flotation cells for secondary recovery of bitumen, and a coarse sands tailings (CST) which are withdrawn at the bottom of the PSC. The CST may comprise water and the majority of solids from the oil sand slurry.

[0055] The phrase “processing the oil sand slurry stream into bitumen froth, fine tailings (FT), and coarse sand tailings (CST), including using a primary separation cell (PSC)” is used herein. The term “including” in this phrase implies that while FT may be not produced directly by the PSC, its production includes processing by the PSC. FT may be produced by processing a middlings stream in flotation cells to produce FT.

[0056] The water chemistry parameter may be any suitable water chemistry parameter and may comprise at least one of pH, electrical conductivity, content of at least one metal, content of at least one cation, content of at least one anion, and ionic strength. The water chemistry parameter may comprise content of at least one of calcium, magnesium, sodium, potassium, bicarbonate, and sulfate. The water chemistry parameter may comprise pH. The water chemistry parameter may comprise electrical conductivity. The water chemistry parameter may comprise at least one of Na^+ , K^+ , Ca^{++} , Mg^{++} cation content. The water chemistry parameter may comprise Ca^{++} or Mg^{++} cation content.

[0057] Adjusting process temperature may comprise adjusting the temperature in the PSC or in the ore preparation plant upstream of the PSC.

[0058] Adjusting the oil sand slurry stream composition may comprise adjusting an amount (i.e., rate) of ore and/or fines introduced to the system, and/or the water:ore ratio in the oil sand slurry stream.

[0059] Adjusting water addition to the PSC may comprise adjusting the amount of water added to the PSC either via the oil sand slurry stream and/or as dilution water added to the PSC.

[0060] Step e) may particularly comprise adjusting the dosage of the process aid added to the oil sand slurry stream. Step e) may further comprise adjusting at least one of the process temperature, the mixing conditions, the oil sand slurry stream composition, and the water addition to the PSC.

[0061] The water chemistry parameter may be measured with an online water chemistry analyzer. The water chemistry analyzer may send a signal to a setpoint hub, wherein the set point hub additionally receives a desired setpoint. The setpoint hub may compare the signal from the water chemistry analyzer to the desired setpoint, and send a signal to a feedback controller. The feedback controller may send a signal to a controller which controls the adjusting the dosage of the process aid added to the oil sand slurry stream, and/or the oil sand slurry stream composition. The oil sand slurry stream composition may be adjusted, wherein the adjusting of the oil sand slurry stream composition comprises adjusting at least one of a rate of ore introduced to the system, a rate of fines introduced to the system, and a water:ore ratio in the oil sand slurry stream.

[0062] The method may further comprise obtaining an indication of fines content in the oil sand slurry stream and further adjusting at least one of the dosage of the process aid added to the oil sand slurry stream, the process temperature, the mixing conditions, the oil sand slurry stream composition, and the water addition to the PSC, based at least in part, on the fines content. The water chemistry parameter may be measured with an online water chemistry analyzer. The water chemistry analyzer may send a signal to a setpoint hub, wherein the set point hub additionally receives a desired setpoint. The setpoint hub may compare the signal from the water chemistry analyzer to the desired setpoint, and send a signal to a feedback controller. The feedback controller may send a signal to a controller which controls the adjusting the dosage of the process aid added to the oil sand slurry stream, and/or the oil sand slurry stream composition. The oil sand slurry stream composition may be adjusted, wherein the adjusting of the oil sand slurry stream composition comprises adjusting at least one of a rate of ore introduced to the system, a rate of fines introduced to the system, and a water:ore ratio in the oil sand slurry stream. The indication of fines in the oil sand slurry stream may comprise measuring a natural radiation parameter of the oil sand slurry stream. The natural gamma

radiation detection may comprise measuring gamma radiation emitted during decay of potassium-40 (K40), uranium-238, or thorium 232.

[0063] Steps a) to d) may be effected continuously. Step e) may be effected automatically. Step c) may be effected online, inline, offline, or atline.

[0064] Figs. 13-15 are schematics of methods including adjusting process aid dosage, ore tonnage, and water and/or water:ore ratio, respectively, based on a measured water chemistry parameter.

[0065] Fig. 13 is a schematic of a method including adjusting process aid dosage based on a measured water chemistry parameter. An oil sand slurry stream (1302) comprising mined bituminous ore is mixed with water in an ore preparation plant (OPP) (1304). The oil sand slurry stream (1302) is passed through hydro-transport (HT) (1306) and is introduced into a primary separation cell (PSC) (1310). The PSC produces bitumen froth (1312), middlings (1314), and coarse sand tailings (CST) (1316). The middlings are introduced into flotation cells (1318) producing fine tailings (FT) (1320). A process aid (1322) (e.g., caustic) is added to the oil sand slurry stream (1302). The stars in Fig. 13 illustrate a water chemistry parameter measurement taken of at least one of the oil sand slurry stream (1302), the FT (1320), the CST (1316), and a middling layer inside the PSC (1324). For simplicity in the Figure, the water chemistry parameter measurements at two locations, the FT (1320) and the CST (1316) are shown feeding back (1325 and 1326) from water chemistry analyzer (A) to a set point hub (1328). Desired set point data (1330) is fed into the set point hub (1328). Based on the water chemistry parameter measurement(s) (1325 and 1326) and the desired set point data (1330), a set point offset signal (1332) may be fed to a feedback controller (1334). A control signal (1336) may be sent from the feedback controller (1334) to a controller (1338). Fig. 13 includes a feed-forward component starting with a fines content measurement from a fines analyzer (FA) (1340) of the oil sand slurry stream (1302) which may be optionally included in the process configuration. This measurement (1340) is passed to a feedforward controller (1342) and on to the controller (C) (1338). The controller (1338) may send a signal to a process aid dosage controller (1344) for dosing process aid (1322) addition. It should be noted that while, for

simplicity, the description Figure 13 (and similarly for Figures 14 and 15) only illustrate the feedback signal from water chemistry analyzers (A) located on process lines 1320 and 1316 of the water-based oil extraction process, that similarly, the water chemistry analyzers (A) shown on line 1302, as well as located at the middling layer inside the PSC (1324), can be utilized in a similar manner. Additionally, the water chemistry analyzers (A) as shown in Figures 13-15 can be used either individually or in any combination.

[0066] Fig. 14 is a schematic of a method including adjusting ore tonnage based on a measured water chemistry parameter. An oil sand slurry stream (1402) comprising mined bituminous ore is mixed with water in an ore preparation plant (OPP) (1404). The oil sand slurry stream (1402) is passed through hydro-transport (HT) (1406) and is introduced into a primary separation cell (PSC) (1410). The PSC produces bitumen froth (1412), middlings (1414), and coarse sand tailings (CST) (1416). The middlings are introduced into flotation cells (1418) producing fine tailings (FT) (1420). The stars in Fig. 14 illustrate a water chemistry parameter measurement taken of at least one of the oil sand slurry stream (1402), the FT (1420), the CST (1416), and a middling layer inside the PSC (1424). The water chemistry parameter measurement may also be taken from the bitumen froth or from the middling from the PSC. For simplicity in the Figure, the water chemistry parameter measurements at two locations, the FT (1420) and the CST (1416) are shown feeding back (1425 and 1426) from a water chemistry analyzer (A) to a set point hub (1428). Desired set point data (1430) is fed into the set point hub (1428). Based on the water chemistry parameter measurement(s) (1425 and 1426) and the desired set point data (1430), a set point offset signal (1432) may be fed to a feedback controller (1434). A control signal (1436) may be sent from the feedback controller (1434) to a controller (C) (1438). Fig. 14 includes a feedforward component starting with a fines content measurement from a fines analyzer (FA) (1440) of the oil sand slurry stream (1402) which may be optionally included in the process configuration. This measurement (1440) is passed to a feedforward controller (1442) and on to the controller (1438). The controller (1438) may send a signal to a feed rate/composition controller (1446) for controlling the oil sand slurry stream (1402) rate and/or composition of the oil sand slurry stream (or its individual components, such as controlling the overall rate of ore to the system) into the ore preparation plant OPP (1404).

[0067] Fig. 15 is a schematic of a method including adjusting water and/or water:ore ratio based on a measured water chemistry parameter. An oil sand slurry stream (1502) comprising mined bituminous ore is mixed with water in an ore preparation plant (OPP) (1504). The oil sand slurry stream (1502) is passed through hydro-transport (HT) (1506) and is introduced into a primary separation cell (PSC) (1510). The PSC produces bitumen froth (1512), middlings (1514), and coarse sand tailings (CST) (1516). The middlings are introduced into flotation cells (1518) producing fine tailings (FT) (1520). A process aid (1522) (e.g caustic) is added to the oil sand slurry stream (1502). The stars in Fig. 15 illustrate a water chemistry parameter measurement taken of at least one of the oil sand slurry stream (1502), the FT (1520), the CST (1516), and a middling layer inside the PSC (1524). The water chemistry parameter measurement may also be taken from the bitumen froth or from the middling from the PSC. For simplicity in the Figure, the water chemistry parameter measurements at two locations, the FT (1520) and the CST (1516) are shown feeding back (1525 and 1526) from a water chemistry analyzer (A) to a set point hub (1528). Desired set point data (1530) is fed into the set point hub (1528). Based on the water chemistry parameter measurement(s) (1525 and 1526) and the desired set point data (1530), a set point offset signal (1532) may be fed to a feedback controller (1534). A control signal (1536) may be sent from the feedback controller (1534) to a controller (C) (1538). Fig. 15 includes a feedforward component starting with a fines content measurement from a fines analyzer (FA) (1540) of the oil sand slurry stream (1502) which may be optionally included in the process configuration. This measurement (1540) is passed to a feedforward controller (1542) and on to the controller (1538). The controller (1538) may send a signal to a water/ore dosage controller (1546) for dosing water addition or for controlling a water:ore ratio.

[0068] The scope of the claims should not be limited by particular embodiments set forth herein, but should be construed in a manner consistent with the specification as a whole.

CLAIMS:

1. A method comprising:
 - a) providing an oil sand slurry stream to a water-based extraction process;
 - b) adding a process aid to the oil sand slurry stream;
 - c) processing the oil sand slurry stream into bitumen froth, fine tailings (FT), and coarse sand tailings (CST), including using a primary separation cell (PSC);
 - d) measuring a water chemistry parameter of at least one of the oil sand slurry stream, the FT, the CST, the bitumen froth, middlings from the PSC, and a middling layer inside the PSC; and
 - e) based on the measured water chemistry parameter, adjusting at least one of the following in the water-based extraction process: a dosage of the process aid added to the oil sand slurry stream, process temperature, a mixing condition, an oil sand slurry stream composition, and a water addition to the PSC.
2. The method of claim 1, wherein the water chemistry parameter comprises at least one of pH, electrical conductivity, content of at least one metal, content of at least one cation, content of at least one anion, and ionic strength.
3. The method of claim 1, wherein the water chemistry parameter comprises pH.
4. The method of claim 1, wherein the water chemistry parameter comprises electrical conductivity.
5. The method of claim 1, wherein the water chemistry parameter comprises content of at least one of calcium, magnesium, sodium, potassium, bicarbonate, and sulfate.
6. The method of claim 2, wherein the water chemistry parameter comprises at least one of Na^+ , K^+ , Ca^{++} , Mg^{++} cation content.

7. The method of claim 6, wherein the water chemistry parameter comprises Ca^{++} or Mg^{++} cation content.
8. The method of any one of claims 1 to 7, wherein step e) comprises adjusting the dosage of the process aid added to the oil sand slurry stream.
9. The method of any one of claims 1 to 8, wherein the process aid comprises caustic.
10. The method of claim 8 or 9, wherein step e) further comprises adjusting at least one of the process temperature, the oil sand slurry stream composition, and the water addition to the PSC.
11. The method of any one of claims 1 to 7, wherein step e) comprises adjusting at least one of the process temperature, the mixing conditions, the oil sand slurry stream composition, and the water addition to the PSC.
12. The method of any one of claims 1 to 11, wherein the water chemistry parameter is measured with an online water chemistry analyzer.
13. The method of claims 12, wherein the water chemistry analyzer sends a signal to a setpoint hub, wherein the set point hub additionally receives a desired setpoint.
14. The method of claim 13, wherein the setpoint hub compares the signal from the water chemistry analyzer to the desired setpoint, and sends a signal to a feedback controller.
15. The method of claim 14, wherein the feedback controller sends a signal to a controller which controls the adjusting the dosage of the process aid added to the oil sand slurry stream, and/or the oil sand slurry stream composition.

16. The method of claim 15, comprising adjusting the oil sand slurry stream composition, wherein the adjusting of the oil sand slurry stream composition comprises adjusting at least one of a rate of ore introduced to the system, a rate of fines introduced to the system, and a water:ore ratio in the oil sand slurry stream.
17. The method of any one of claims 1 to 11, further comprising obtaining an indication of fines content in the oil sand slurry stream and further adjusting at least one of the dosage of the process aid added to the oil sand slurry stream, the process temperature, the mixing conditions, the oil sand slurry stream composition, and the water addition to the PSC based, at least in part, on the fines content.
18. The method of claim 17, wherein the fines content is measured with an online fines analyzer.
19. The method of claim 18, wherein the fines analyzer sends a signal to a feedforward controller.
20. The method of claim 19, wherein the feedforward controller sends a signal to a controller which controls the adjusting the dosage of the process aid added to the oil sand slurry stream, and/or the oil sand slurry stream composition.
21. The method of claim 20, comprising adjusting the oil sand slurry stream composition wherein the adjusting of the oil sand slurry stream composition comprises adjusting at least one of a rate of ore introduced to the system, a rate of fines introduced to the system, and a water:ore ratio in the oil sand slurry stream.
22. The method of claim 17, wherein the indication of fines in the oil sand slurry stream comprises measuring a natural radiation parameter of the oil sand slurry stream.

23. The method of claim 22, wherein the natural gamma radiation detection comprises measuring gamma radiation emitted during decay of potassium-40, uranium-238, or thorium-232.
24. The method of any one of claims 1 to 23, wherein the oil sand slurry stream stems from mined oil sand.
25. The method of any one of claims 1 to 24, wherein the oil sand slurry stream comprises 7 to 16 wt. % bitumen, 1 to 7 wt. % water, and 77 to 92 wt. % solids.
26. The method of any one of claims 1 to 22, wherein the oil sand slurry stream comprises 10 to 12.5 wt. % bitumen, 2.5 to 6 wt. % water, and 81.5 to 87.5 wt. % solids.
27. The method of any one of claims 1 to 24, wherein steps a) to d) are effected continuously.
28. The method of any one of claims 1 to 27, wherein step e) is effected automatically.
29. The method of any one of claims 1 to 28, wherein step c) is effected online, inline, offline, or atline.

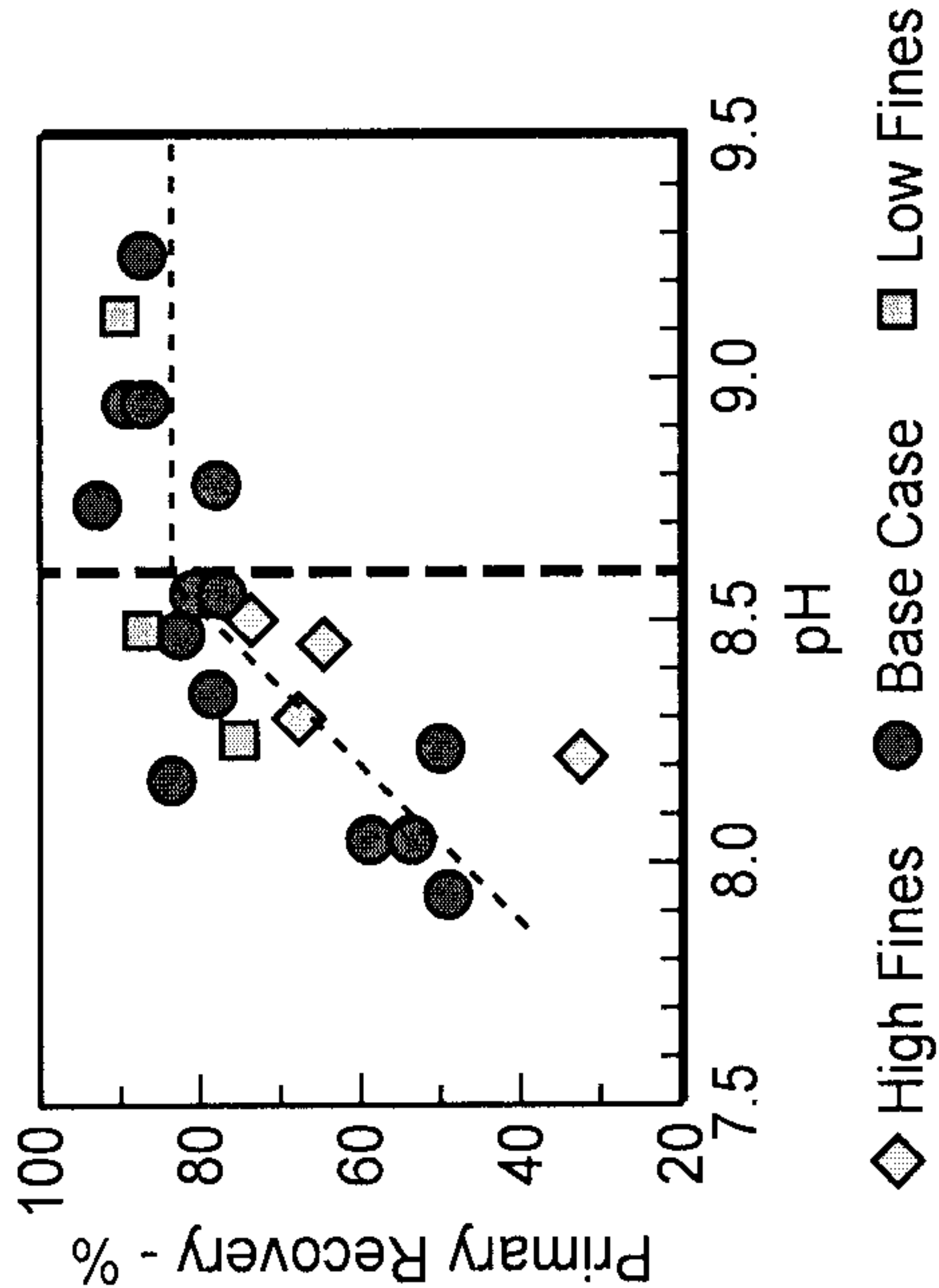


FIG. 1

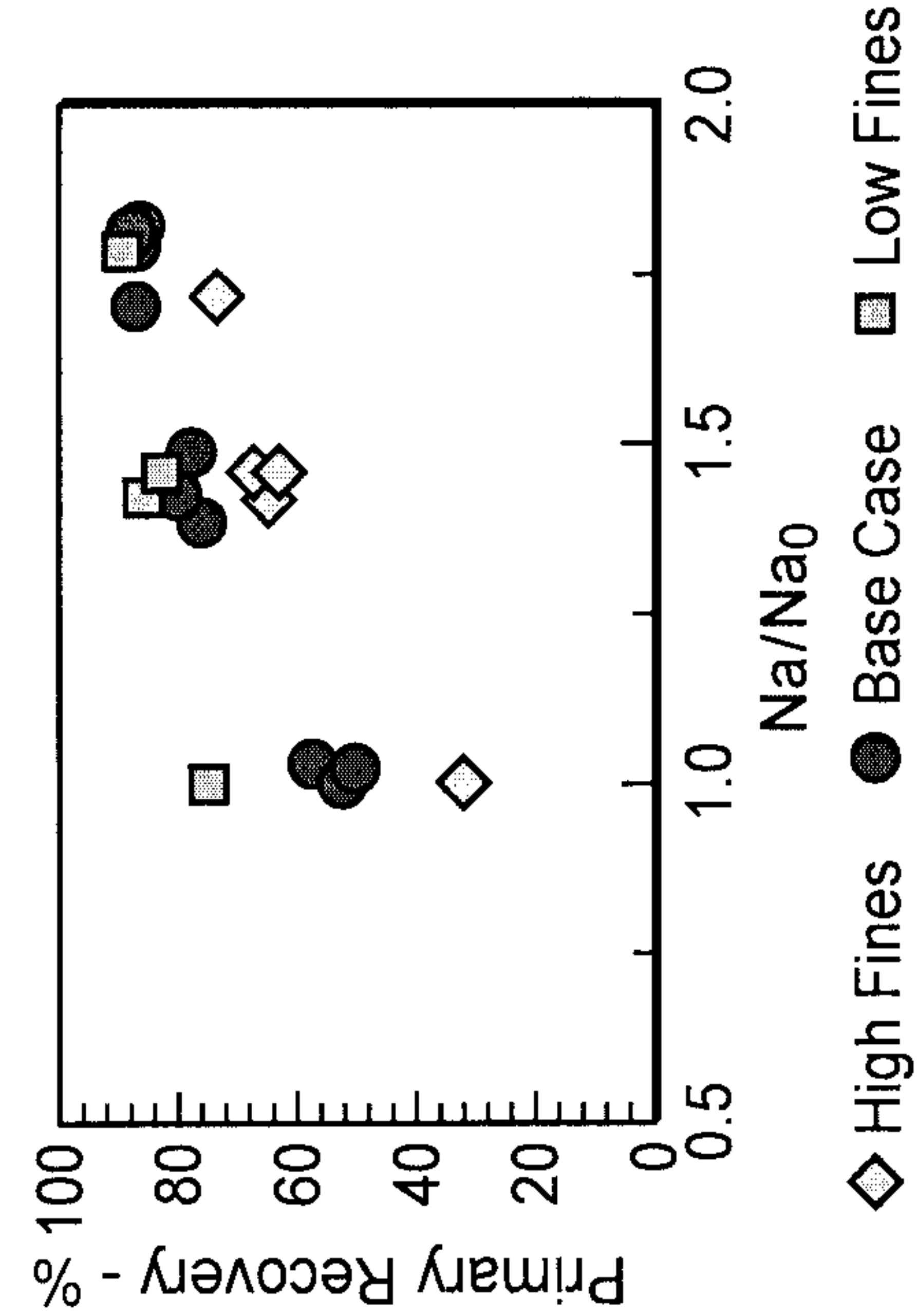


FIG. 2

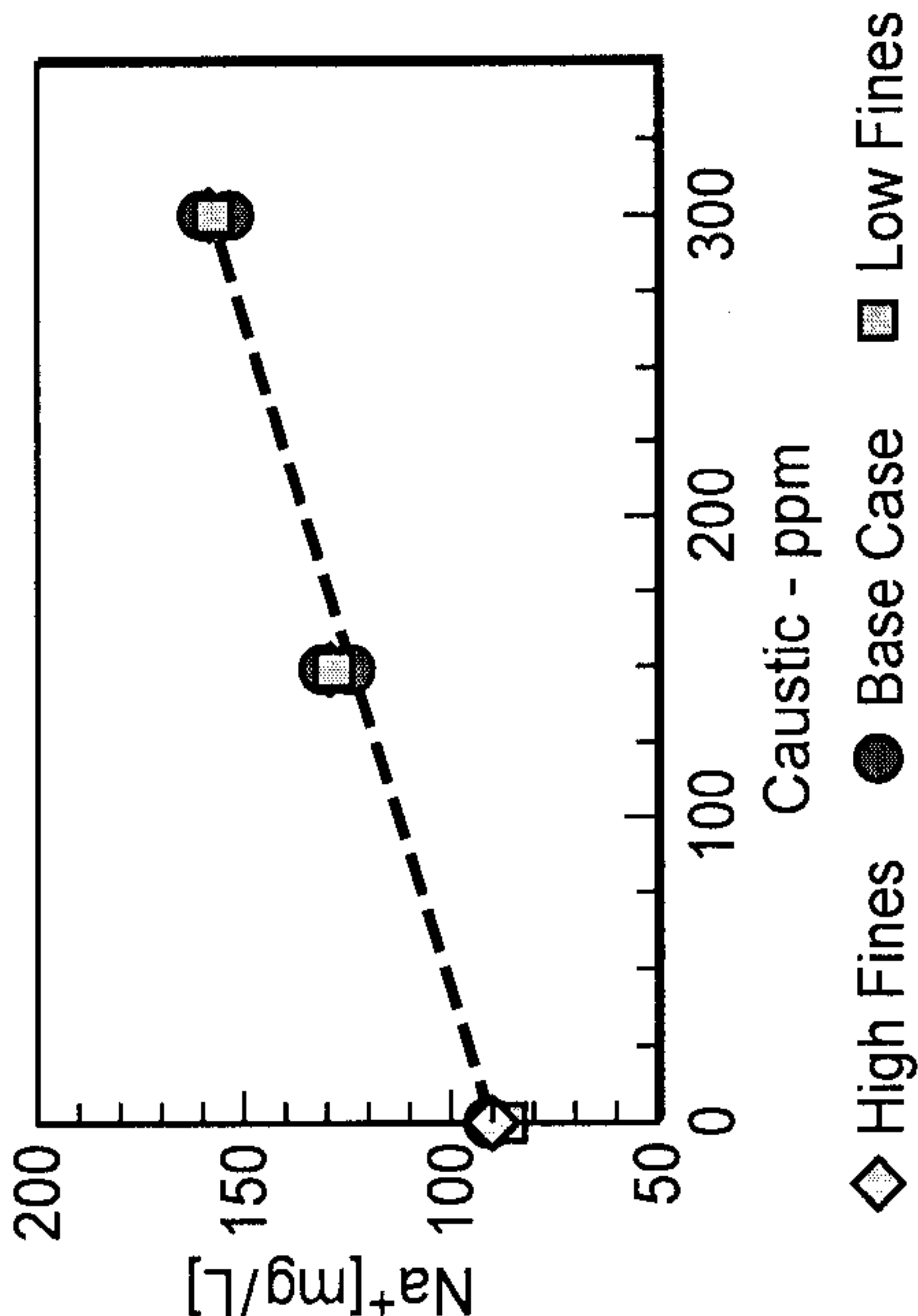


FIG. 3

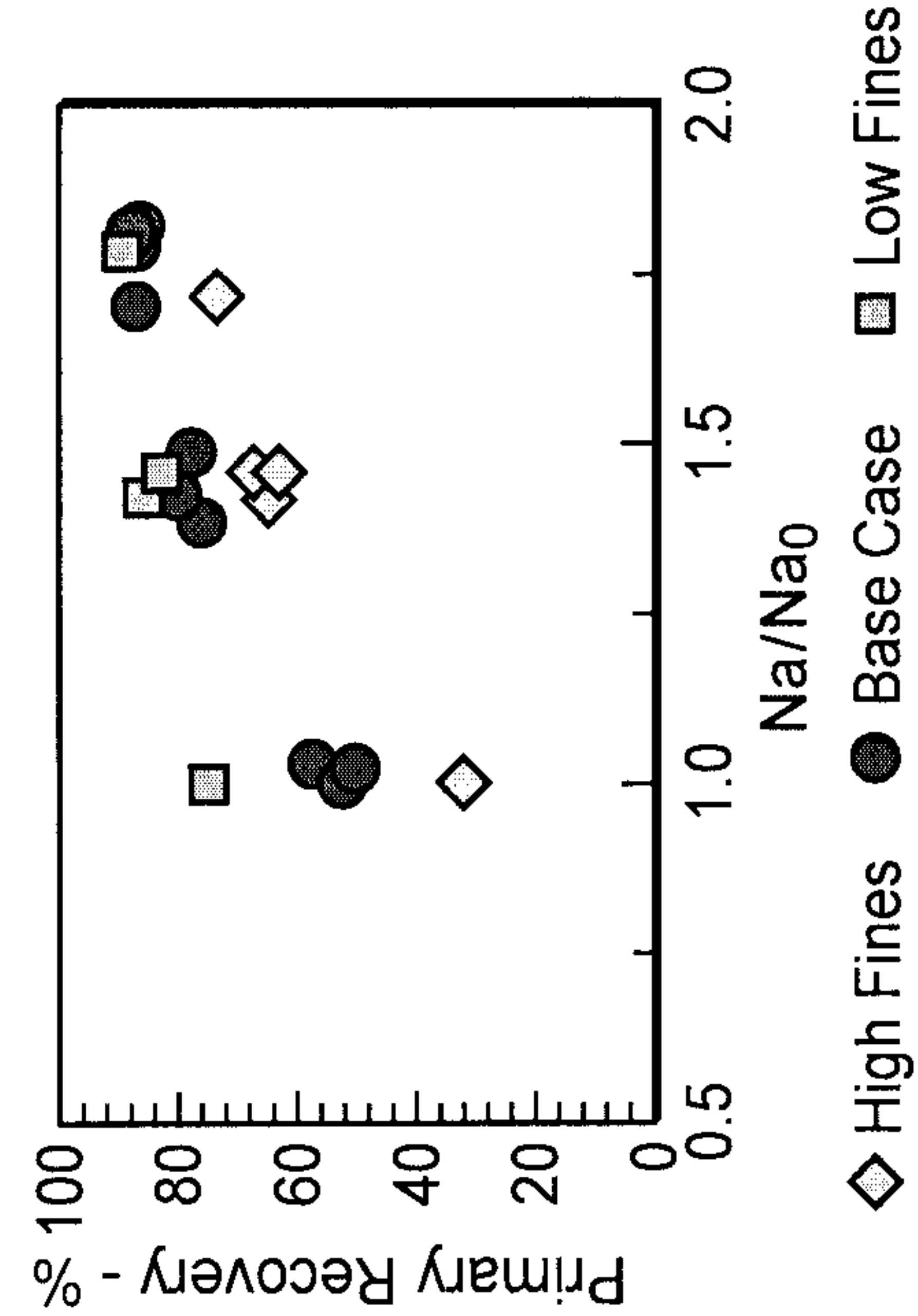


FIG. 4

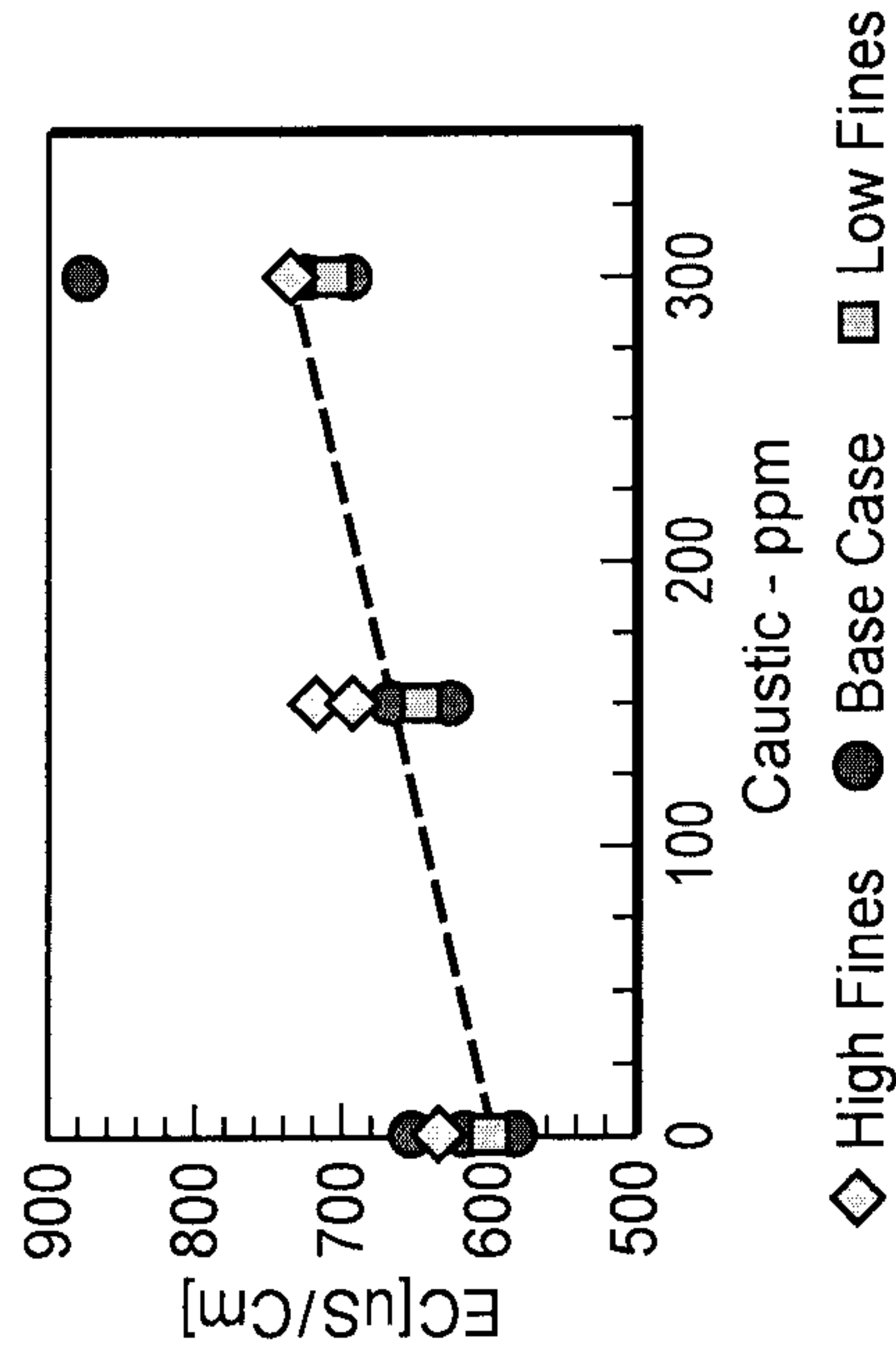


FIG. 5

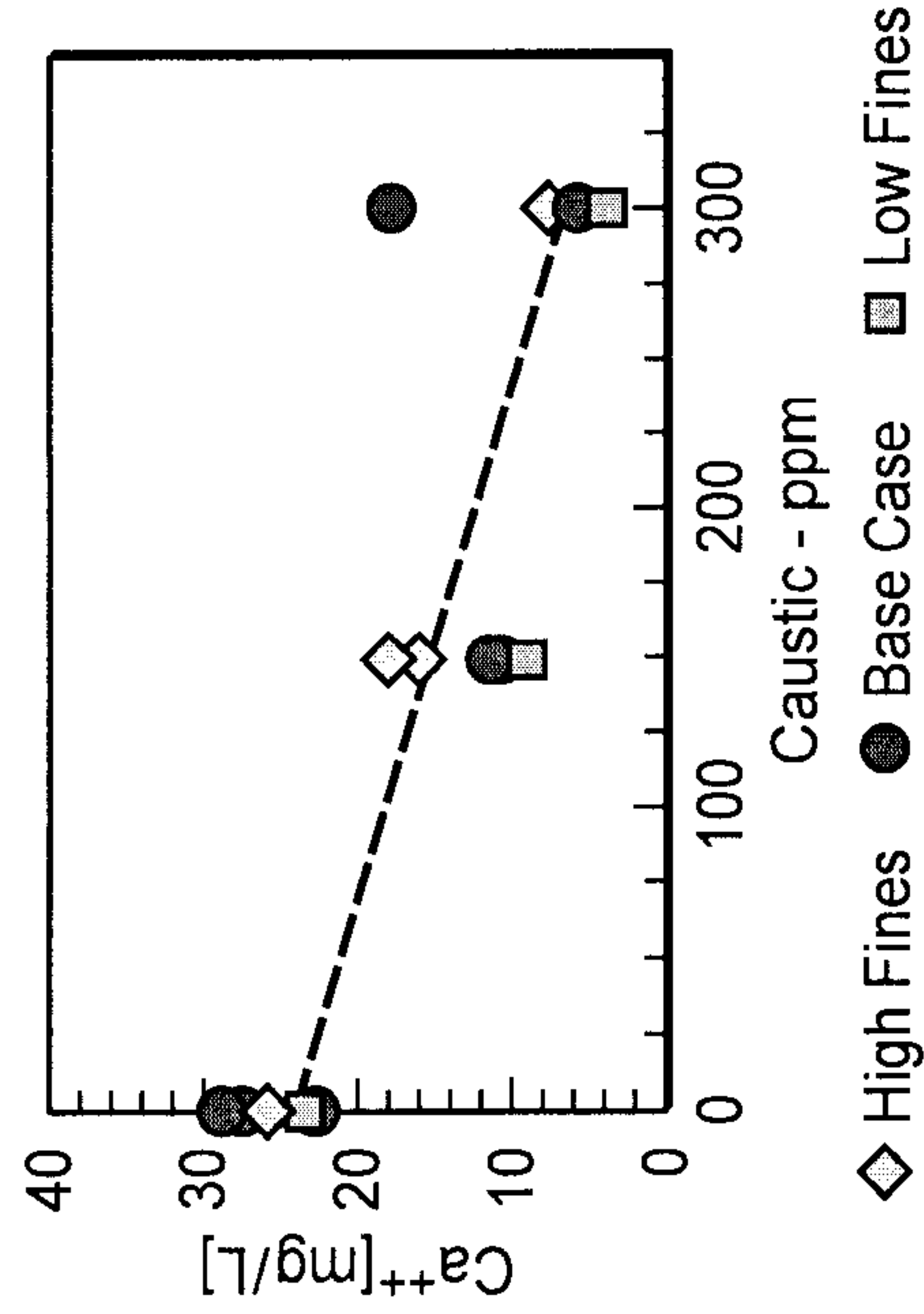


FIG. 7

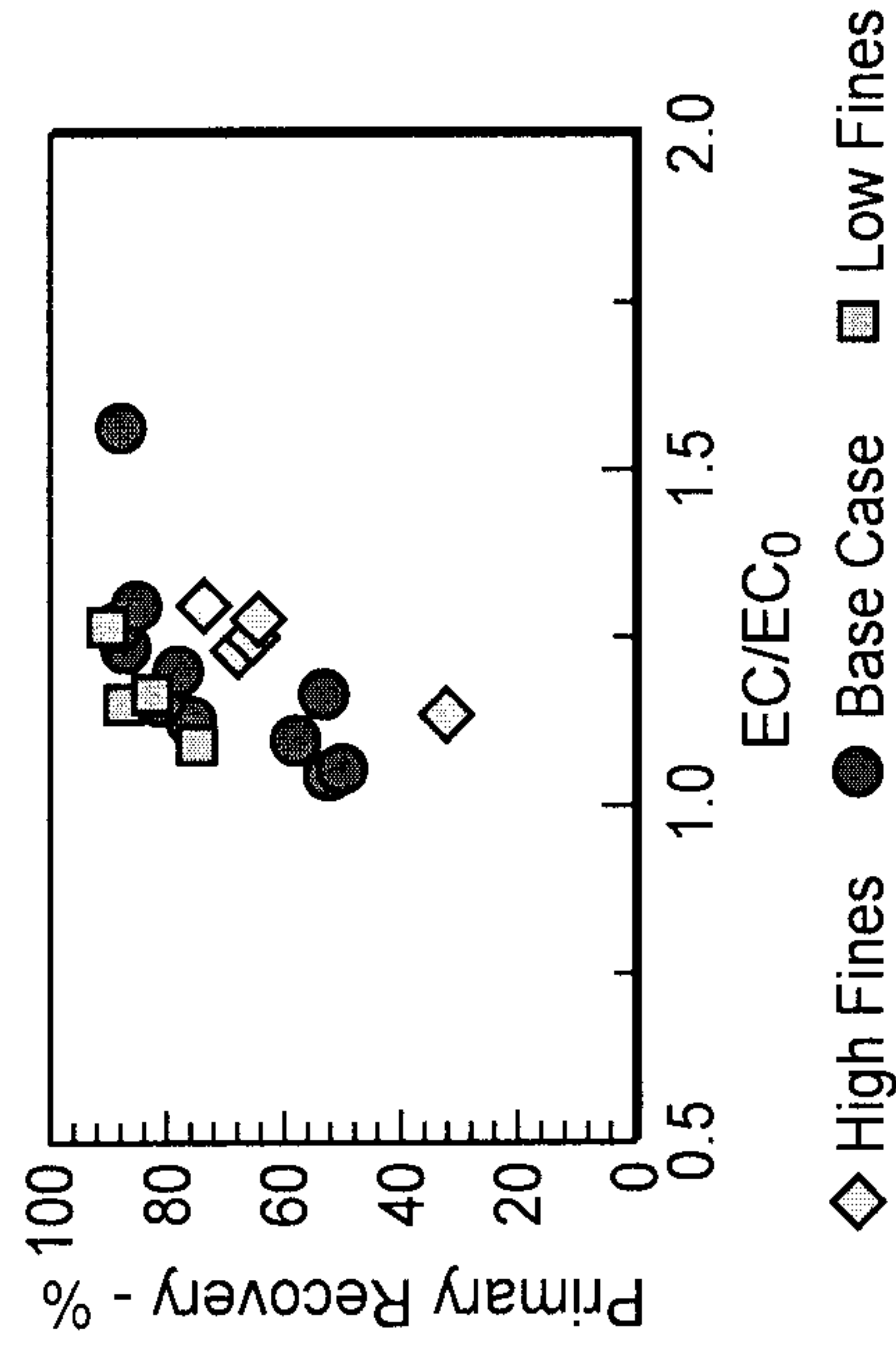


FIG. 6

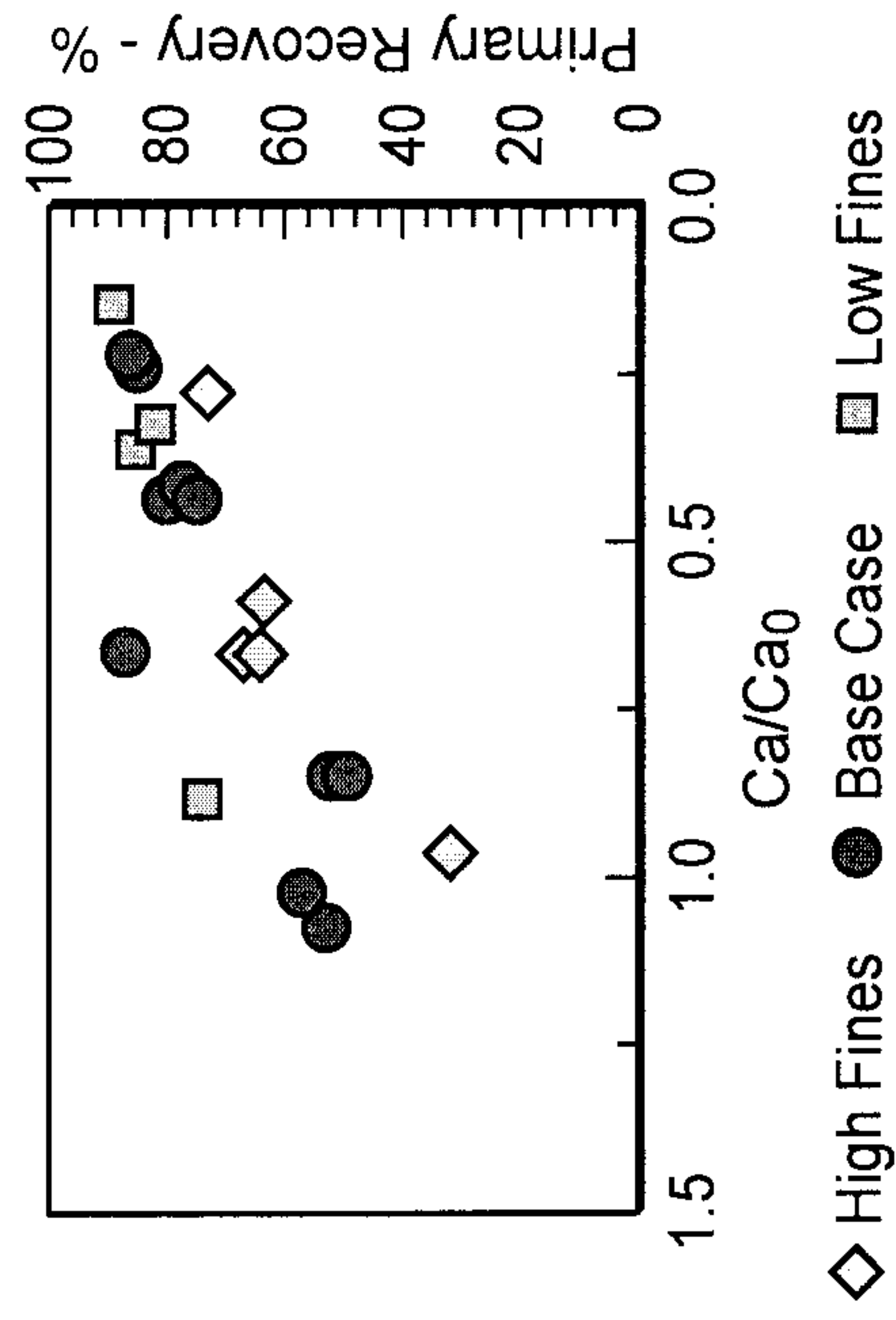


FIG. 8

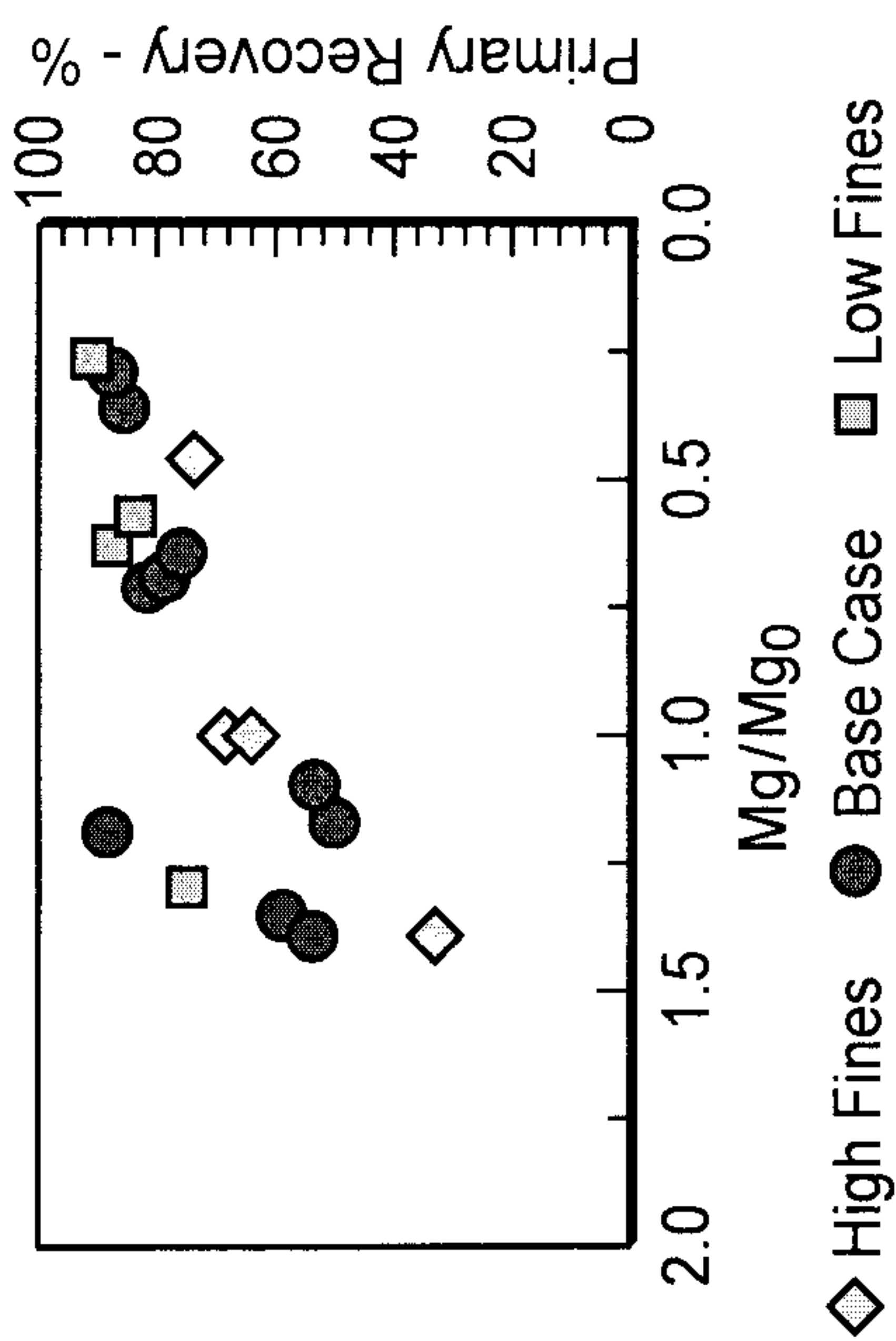


FIG. 10

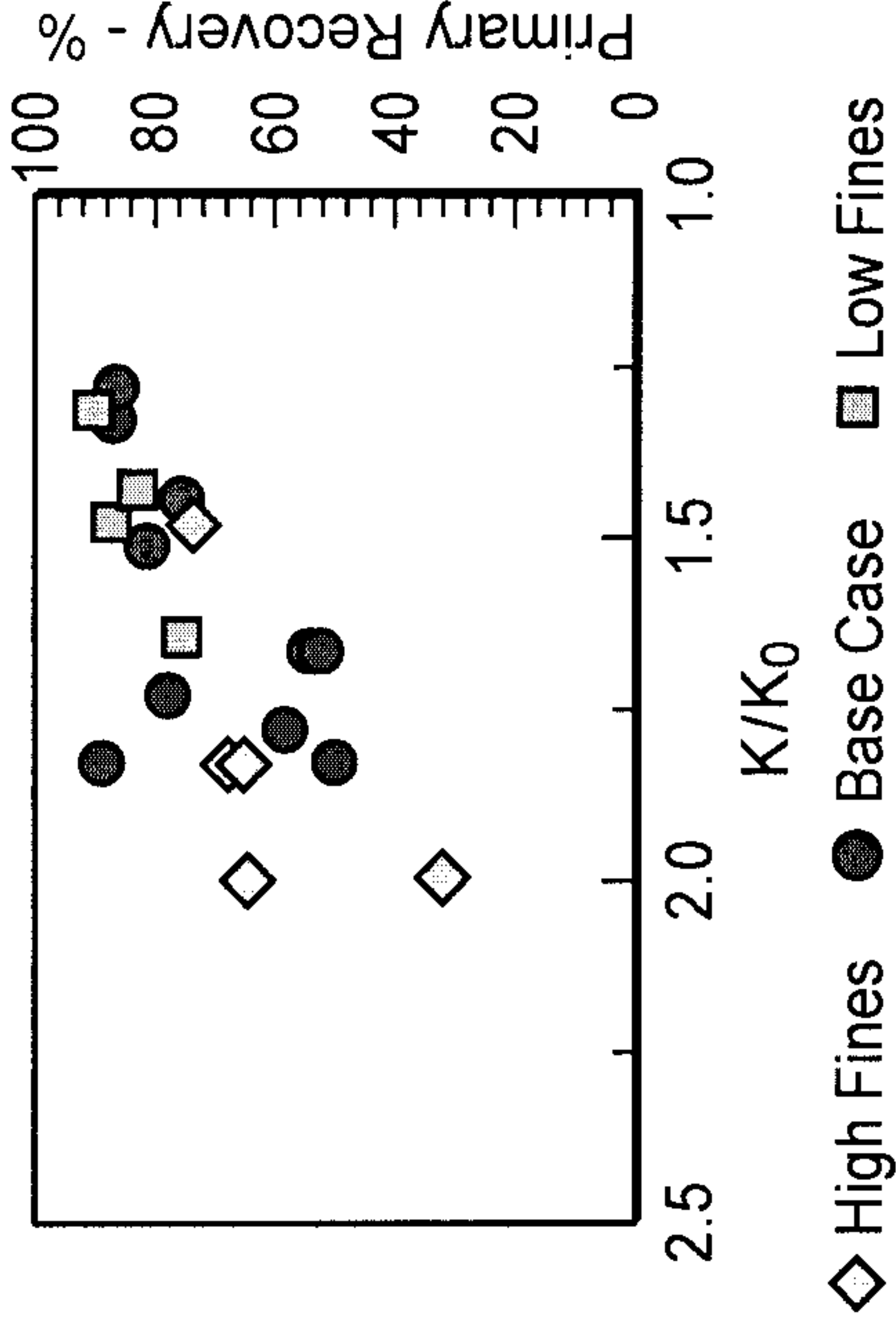


FIG. 12

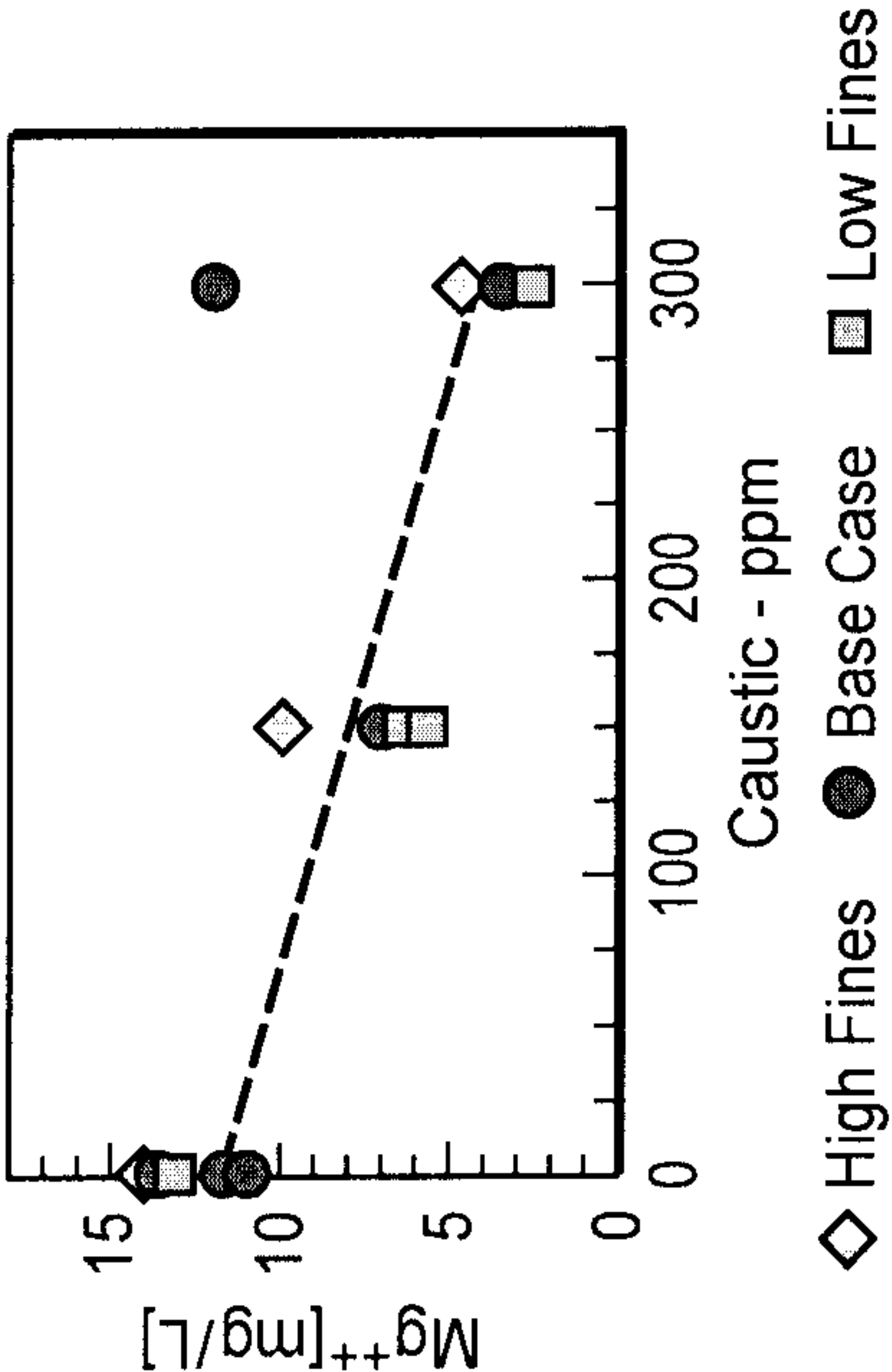


FIG. 9

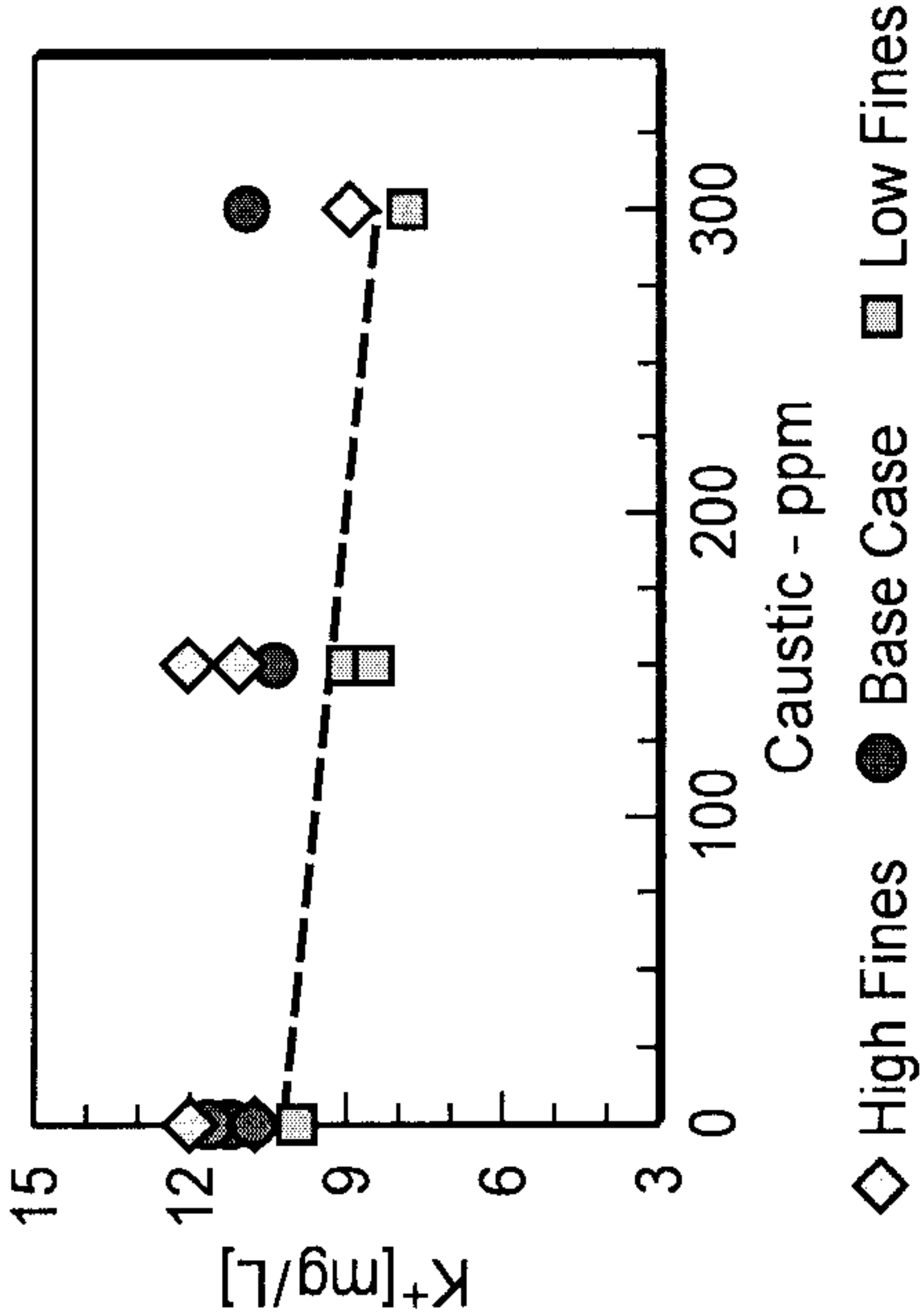
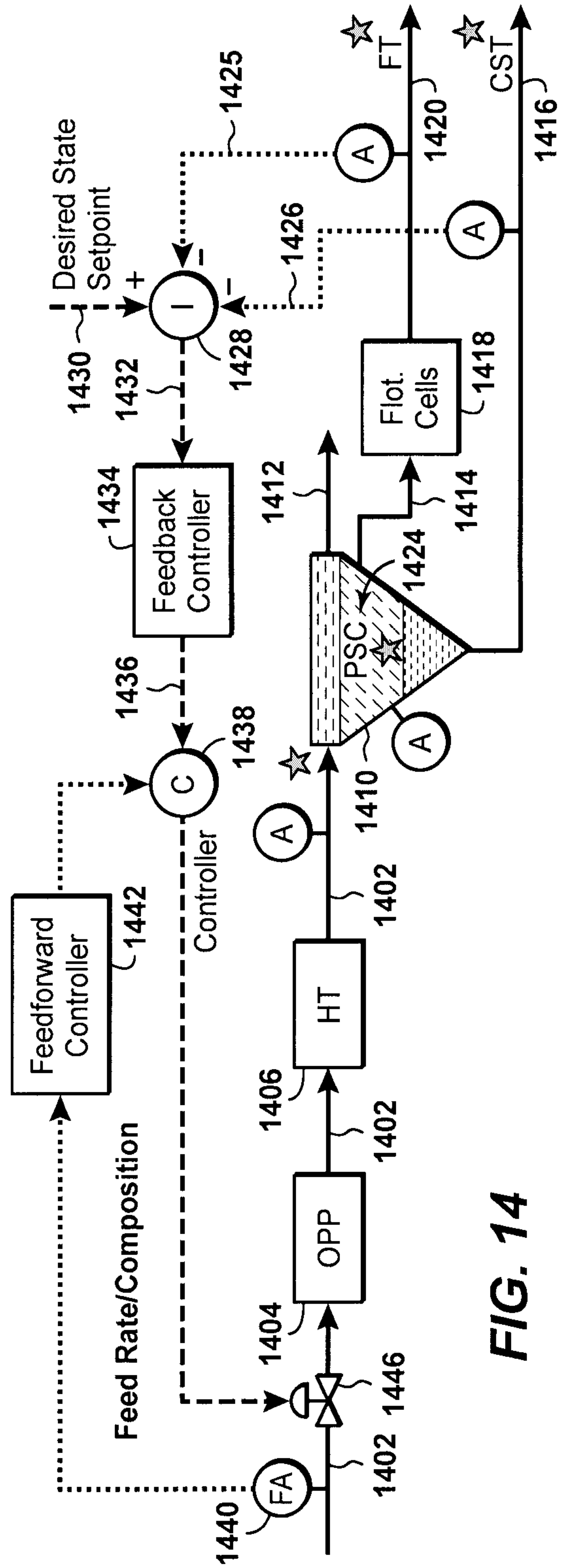
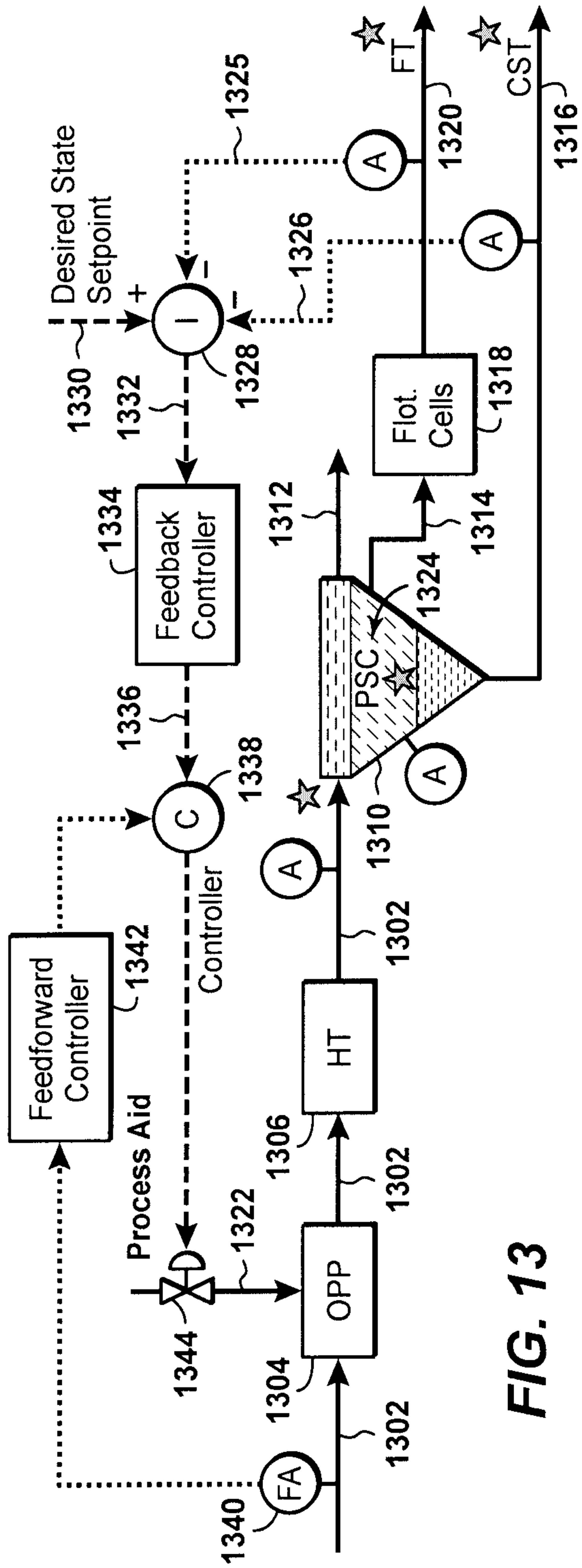


FIG. 11



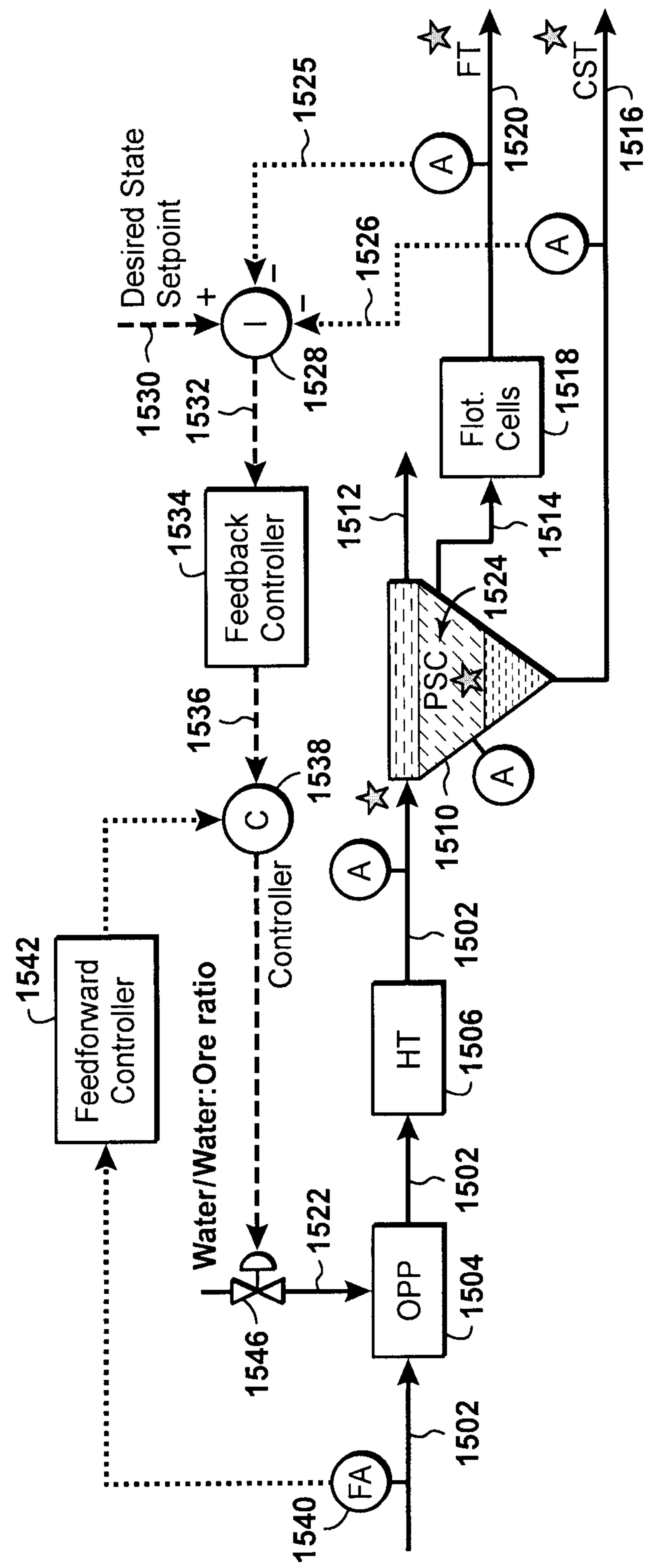


FIG. 15