VST inc

Voice Systems Technology, Inc.

Universal Brewing Control System
ExtractMoJo™

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Modernize Your Brewing Control Process

For Those In Search of the Ultimate Cup

Extract**MoJo™** software is designed for ease-of-use, and provides all the tools needed for designing proper extraction protocols to internationally recognized gold-cup standards using a variety of coffee brewing methods. The Extract**MoJo™** Bundle includes the world's first dedicated coffee refractometer to provide a complete coffee design solution for commercial or professional home use.

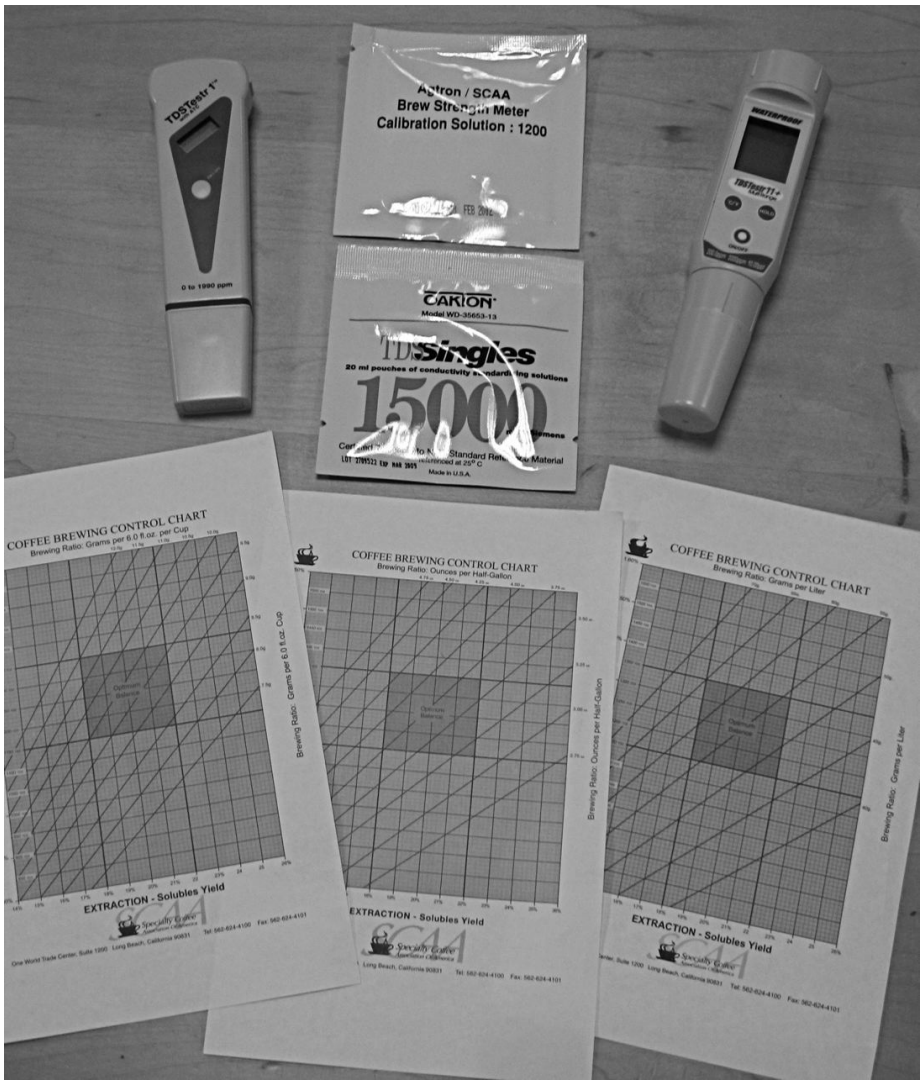
Circa 1950s through 1960s

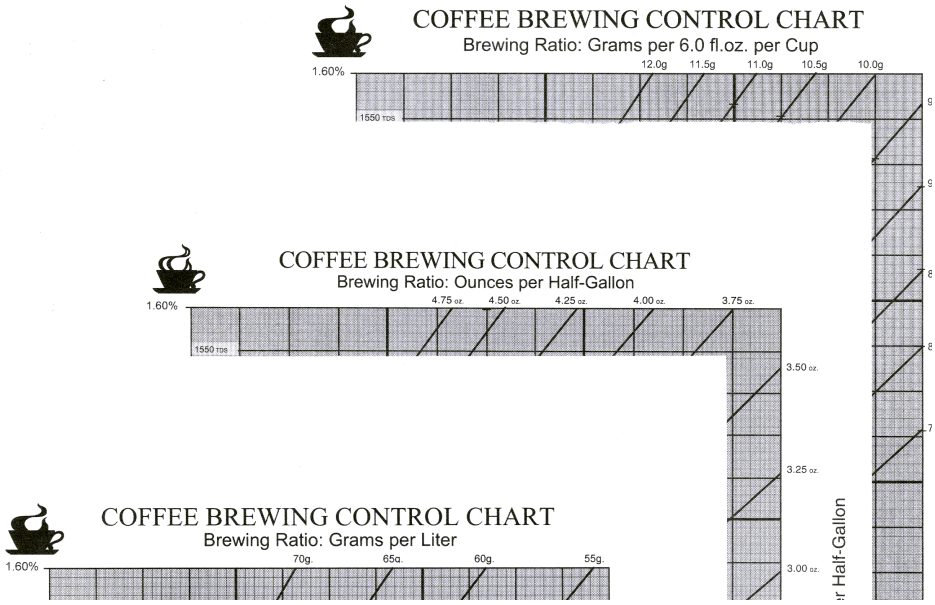
Internationally accepted "gold cup" standards established the basic science of proper proportions of coffee and water (brew formula) and extraction, but the methods for measuring final results were slow, expensive and lacked the immediate feedback necessary to make adjustments for time, turbulence, temperature, and grade of grind.

Extract**MoJo™** allows roasters, cafes, restaurants, professional chefs and beverage consultants to design, measure and calibrate most any brewing equipment for proper extraction under an extremely wide variety of brewing conditions.

Extract**MoJo™** includes the ability to design, measure, save, chart, print and recall unlimited coffee brewing recipes. Extract**MoJo™** improves coffee quality dramatically, allowing users to keep extraction and strength to the desired ranges, for

consistently great tasting coffee without the guesswork and limitations of former techniques.





The original brewing control charts were limited in their usefulness, because users were forced to use specific units, as well as fixed portion sizes. Conversion between units was not considered, and water density and volume were not considered as a function of temperature, resulting in errors in the brew formula. Measurement of Total Dissolved Solids (%TDS) in order to make use of the charts has been unreliable, time consuming, and expensive.

Extract**MoJo™** greatly simplifies these limitations with a new Universal Brewing Control Chart that allows users to use any units of measure, including mixed units (i.e., liters, gallons, grams, ounces) within the same design session and brewing control chart.

In addition, Extract**MoJo™** corrects for errors in previous brewing control charts and brew formulas, by taking into account water density as a function of temperature, and adjusting volume and recipes accordingly, at the actual brew temperatures used.

Finally, the Extract**MoJo™** bundle includes the world's first TDS Refractometer designed specifically for coffee and

espresso.

ExtractMojo™ Overview:

ExtractMoJo™ Software and Refractometer Bundle

Design Extraction Protocols by:

- **Brew Water Volume** or
- **Desired Coffee Yield** or
- **Fixed Coffee Weight**
- **Espresso Mode**

- Design Concentrates for Fresh Brewed Iced Coffee
- Calculate Proper Portions for Desired Strength
- Plots all data on Universal Brewing Control Chart™
- **Universal Brewing Control Chart™** Convert volume/weight and Metric/English units in any combination, including mixed system of units.
- Provides Preference Settings for Target % Extraction
- Save, Recall, Print and eMail Brew Recipes, and export to MoJoToGo™ for the iPhone®

ExtractMojo™ Requirements

Supported operating systems:

- Microsoft Windows 7
- Microsoft Windows XP Professional (Service Pack 2)
- Microsoft Windows 2000 (Latest Service Pack)

Note: Note: **Macintosh Users**

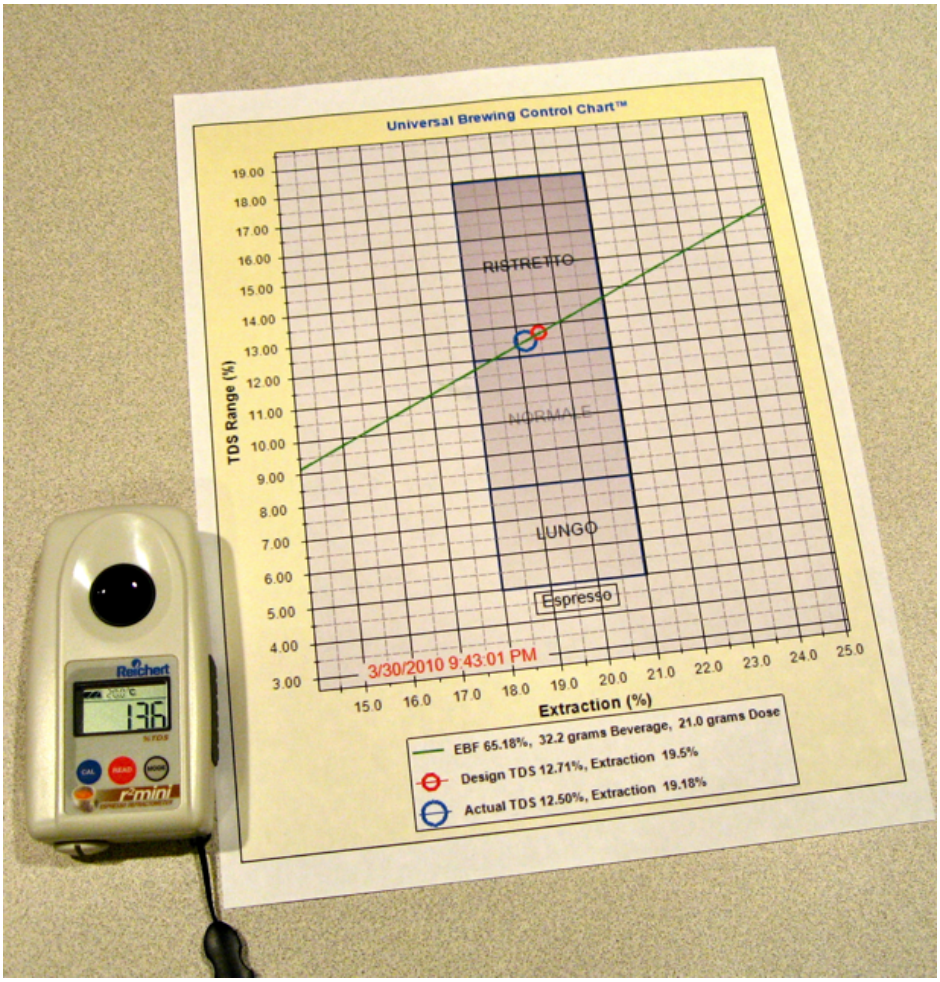
- Mac OS X v10.5.3, VMware Fusion v1.1.3
- Running Microsoft Windows XP Professional

- Internet Explorer 6.0 (Recommended version: IE 7.0)
- Microsoft .NET Framework 2.0

New Software, New Instrument, and New Brewing Control Chart

New Technology

This document teaches you how to use new technology developed by the VST to ensure the perfect extraction on a repeatable basis, using Extract**MoJo™**. The Extract**MoJo™** Bundle includes the new Universal Brewing Control Chart™, interactive and fully configurable Software and the Coffee/ Espresso Refractometer(s), which are used together to design new and troubleshoot existing brewing protocols, and quickly measure, plot, and accurately analyze and correct them.



Design Your Extraction Protocol

Extract**MoJo™** software has three simple windows that help to design and measure your brewing parameters:

- See *Set up Your Brewing Preferences*, page 12, to learn how to set up the basic preferences window.
- See *The ExtractMojo™ Main Application Window*, page 16, to learn how to configure and complete the main application window.
- See How to: *Read the Universal Brewing Control Chart™*, page 17, to learn how to use the data and chart.

Measure Your Success

See *Measuring Dissolved Solids*, page 40, to learn how to read total dissolved solids of your coffee.

Analyze Your Results

Extract**MoJo™** charts all parameters and provides instant feedback so that adjustments, when necessary, can be made quickly and effectively.

Save, Print, eMail Your Brewing Recipes

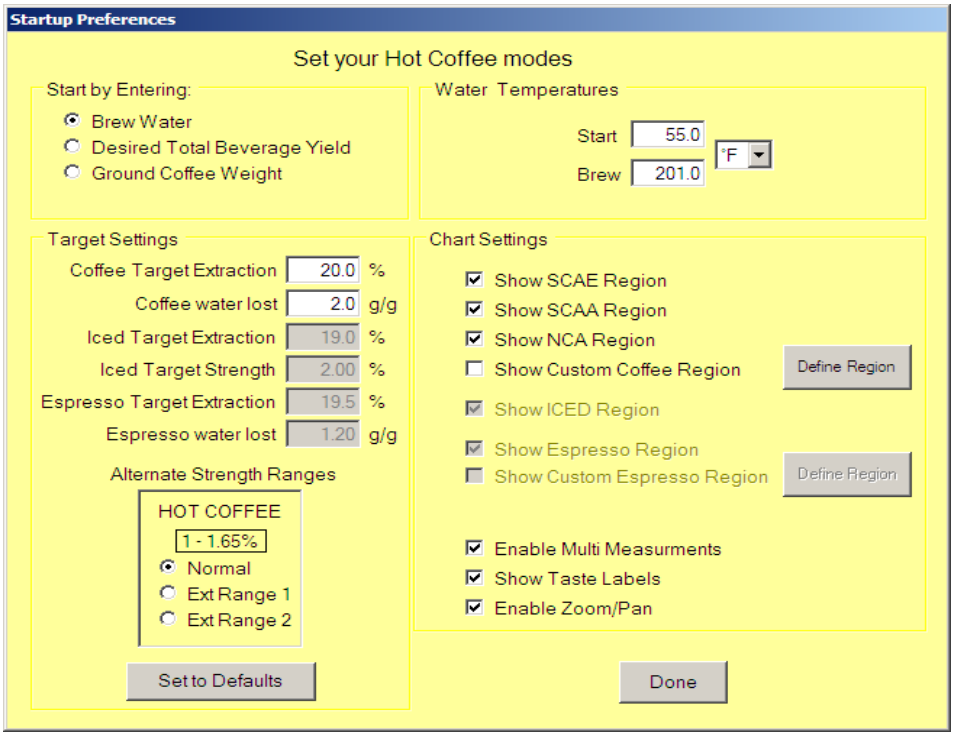
See *Saving your Brew Recipe*, page 43, to learn how to record each session, share your results, document client specific recipes and installations and navigate the region of interest, to land in the "sweet spot."

Set up Your Brewing Preferences

The Startup Preferences window allows you to change basic design preferences. Please note: **Preference Defaults** have been pre-set but can be changed at any time. Preferences (including changes) are saved automatically between application sessions.

HOW TO: **Set User Preferences**

Start your first design session using the Default Preferences, or read the following to learn about and/or see if you want to change any of the Startup Preferences.



1. In the Preferences menu, **select the**: Startup Preferences.
2. Select your preferred design mode, in the **Start by Entering** area in the upper left-hand corner. Select one of the following three buttons to set the method:
   - **Water Volume** -- Select this option to design by entering the **Brew Water Volume** amount. In this mode, the software calculates the **ground coffee** and **coffee yield** amounts based on user **strength TDS** and Extraction Yield selected.
   - **Desired Coffee Yield (Vol)** -- Select this option to design by entering the **Desired Coffee Yield Volume**. In this mode, the software calculates the **ground coffee** and **brew water** amounts based on user **strength TDS** selected.
   - **Ground Coffee Weight** -- Select this option if you are working with a fixed **weight of coffee**, such as a pillow pack. In this mode, the software calculates the **brew water** volume and **coffee yield** volume amounts based on user **strength TDS** selected.

3. **Target Extraction Settings** -- These values should initially be left at the default values. As you gain experience using Extract**MoJo™**, you will learn how to adjust these target extraction values to move a particular coffee to a different area of the brewing control chart for a desired effect.
   - **Coffee Target Extraction** -- For standard drip brewing of coffee, this default is set to 19 percent extraction, where we believe the sweetest extraction yield is achieved. For a sweeter cup, try 18 - 21 percent, depending on taste preferences, the particular coffee, degree of roast, and grade of grind. Note that extracting to lower targeted levels will require more coffee to achieve the same strength preference.
   - **Iced Target Extraction** -- For iced coffee, the default of 19% results in a sweeter cup that is significantly less bitter. With higher elevation grown coffees rich in sugars, this recipe often results in a sweet tasting batch without the use of supplemental sweeteners.
   - **Iced Target Strength** -- For iced coffee, this is the final result of the concentrate after all of the ice has melted at the end of the brew. The concentrate is ready to use immediately after the brew cycle has completed.

To reset the Target Extraction values to the original values, click: **Set to Defaults**.

IMPORTANT: Expanding the available TDS Range

4. During trouble-shooting, you will often find the existing coffee is actually "off the chart." Preferences allow you to extend the Chart Axis ranges to plot points out of normal extraction ranges. If you want the freedom to plan an unusually strong or weak brew, check **Extended Strength Range** in the Target Settings area. This expands the TDS strength range, and is useful for troubleshooting existing protocols that are off the chart.
5. Complete settings in the **Water Temperatures** area in the upper right-hand corner of the window.

   The default is set to the **Fahrenheit** scale. If you prefer, change to **Celsius**.
   - Set the **Brew Temp** to the programmed setting of your brewer (usually 195 - 202 Deg F). VST recommends start-

ing at 201 Deg F for light to medium roasted coffees, slightly lower, i.e., 195 Deg F for dark roasted coffees

– Set the **Start Temp** to what you use at home, which should be equal to either your TAP water temp or room temperature (i.e., for bottled water).

Note: Note: If your Start Temp = Brew Temp (i.e., a commercial brewer with a boiler), leave the Start and Brew Temp presets as described, above.

6. Select the **Chart Settings** preferences in the lower right corner of the Startup Preferences window.
   – **Show Region Labels** -- In the Universal Brewing Control Chart™, selecting this option will display coffee taste preference "regions" defined by different organizations (i.e. SCAA, SCAE, and NCA) as the "**Optimum Balance**" regions.
   – **Show Taste Labels** -- In the Universal Brewing Control Chart™, selecting this option will display the taste defect labels (i.e., bitter or under-developed).
   – **Enable Zoom/Pan** -- This selection allows you to use the mouse and or trackpad controls to zoom/pan the Universal Brewing Control Chart™.
7. Click Done.

   The selected preferences are saved for this and future sessions, and the application returns you to the Extract**MoJo™** main window.

The ExtractMojo™ Main Application Window

Introduction

After your Startup Preferences have been selected, you complete the Brewing protocol design process in the Extract**MoJo™** main application window. Details about how to use the Extract**MoJo™** Main Window are presented in *How to: ExtractMojo™ Main Application Window Modes,* page 20. Prior to reading that section, many readers may benefit from studying *Universal Brewing Control Chart™*, page 17.

Extract**MoJo™** has several exceptional design features:

- It performs all calculations and plots the brewing control chart dynamically and in real time as you change the % TDS strength preference slider control.
- It converts between different types of units instantly and accurately, and allows for mixed units (i.e., brew water in gallons, coffee yield in liters).
- It draws a custom brew formula line on a universal brewing control chart using any combination of selected units in weight and or volume, without restrictions to fixed portions.
- It provides a relative indication of designed recipe to the measured results, in reference to a number of internationally recognized "optimum" brewing ranges.
- It provides a means to troubleshoot current brewing protocols, measure and plot results which immediately identify portioning and extraction errors, and provides a means to correct them.

The window's appearance will depend on the variable you selected to enter as the INPUT data in the Startup Preferences. Extract**MoJo™** displays the computed OUTPUT data immediately below in the next group box of the window, and plots the results on the Universal Brewing Control Chart™ dynamically and in real time in the charting window.

Universal Brewing Control Chart™

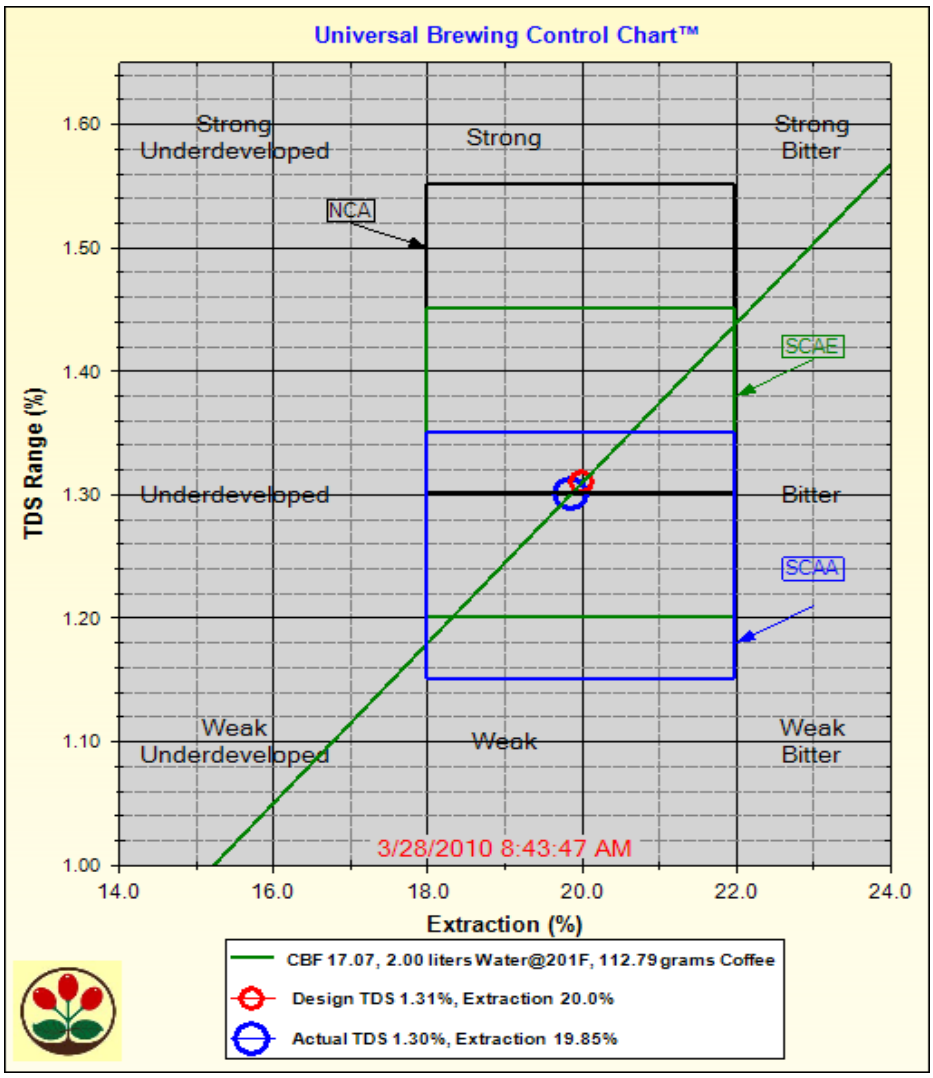
The Universal Brewing Control Chart™ plots the actual brew formula curve, design point and measured results from your input data and % TDS measurements from the Coffee Refractometer.

You will learn how to save, print, email, and recall actual results on the chart later in this document.

HOW TO: **Read the Universal Brewing Control Chart™**

The following picture shows a typical chart, taken from the brew formula discussed in the next section.

You can **display** or **hide** the **Chart** with the **Show/Hide Chart** button in the upper right main Extract**MoJo™** window, and expand the window to fill the display screen using the zoom box in the upper right of the chart window.



The box below the chart shows this data

CBF 17.07, 2.00 liters Water@201F, 112.79 grams Coffee
Design TDS 1.31%, Extraction 20.0%
Actual TDS 1.30%, Extraction 19.85%

- **Brew Formula Ratio** -- The green curve on the chart is the Brew Formula line. It represents the ratio of water to coffee by weight used as your brew formula. Brew Formula, together with the resulting TDS, as well as other factors (temperature, grade of grind, dwell time, and turbulence) will determine the final extraction results of your brew.
- **Red Plot Point** -- The red circle on the Brew Formula line shows the selected strength design target at the default extraction (20%).
- **Blue Measurement of Actual Result** -- The blue circle on the Brew Formula line shows the actual resulting extraction and strength and is plotted as a result of the TDS % measurement on the Coffee refractometer.

Regions of Interest (ROI) for Optimum Balance

- **NCA** ROI -- The region enclosed by the black rectangle shows the target area defined by the Norwegian Coffee Association (NCA).
- **SCAE** ROI -- The region enclosed by the green rectangle shows the target area defined by the Specialty Coffee Association of Europe.
- **SCAA** ROI -- The region enclosed by the blue rectangle shows the target area for gold cup standards as defined by the Specialty Coffee Association of America (SCAA).
- **VST** ROI -- The region enclosed by the purple rectangle shows the target region. This is a user-selectable region which defaults to those preferences VST found to apply to most coffees as the sweetest range of extraction. The Strength limits are those preferred by VST and may also be reset to custom levels.

ExtractMojo™ Main Application Window Modes

The following sections show how to design an extraction protocol in one of three modes for **hot coffee**:

- *How to: Plan Coffee by Water Volume,* **page 20**
- *How to: Design by Coffee Yield,* **page 24**
- *How to: Design by Ground Coffee,* **page 28**
- *Using Extract Espresso Mode*, page 35

The following sections explain special considerations for **iced coffee** and provides a typical example for designing an iced coffee protocol on a 1.5-Gallon commercial brewer.

- *How to: Think About Iced Coffee,* page 31
- *How to: Plan Iced Coffee by Water Volume with a 1.5 Gallon Brewer,* page 31

For other batch sizes of **Iced Coffee**, please refer to the reference section:

- *How to: Plan Iced Coffee by Water Volume with a 0.5 Gallon Brewer,* page 57
- *How to: Plan Iced Coffee by Water Volume with a 1.0 Gallon Brewer,* page 60

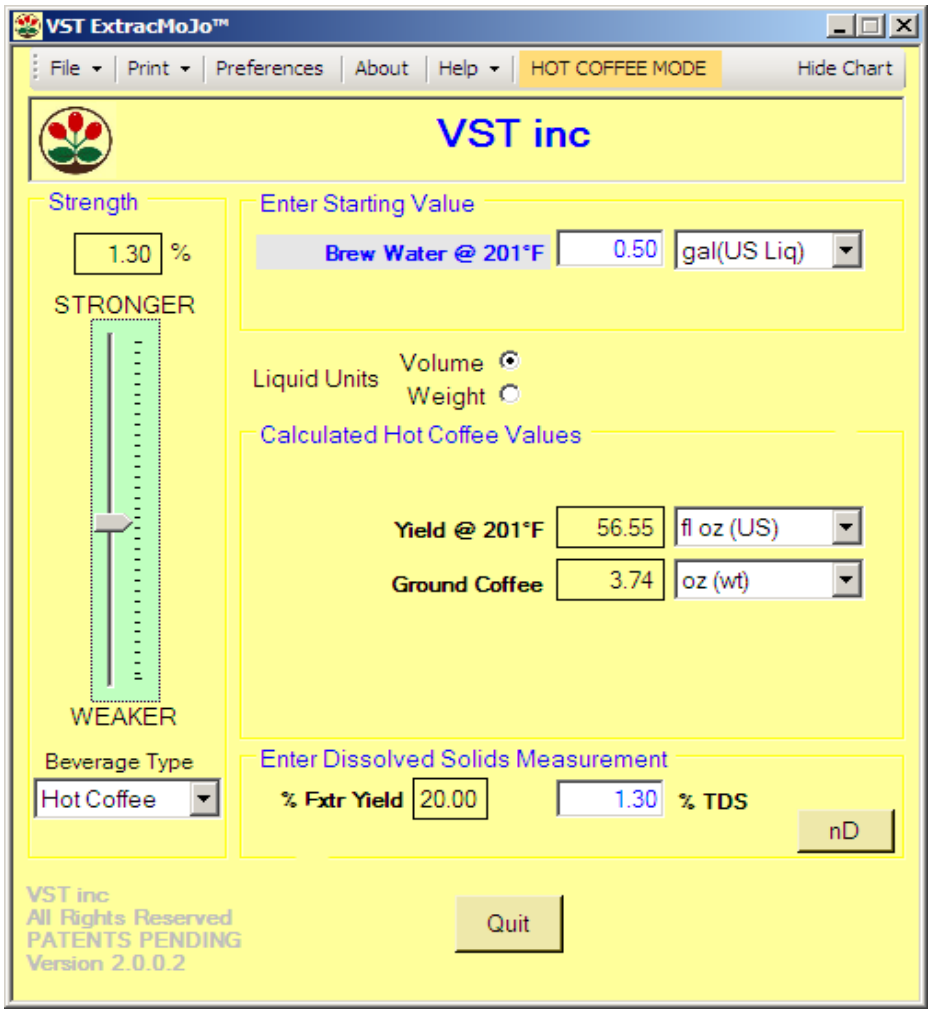
HOW TO: **Plan Coffee by Water Volume**

Planning a brew from the starting water volume is the most common method. The Startup Preferences discussed earlier set up the window for this mode. The brewer is first calibrated, according to manufacturer specifications, to dose exactly the amount of water programmed as the starting brew water volume.

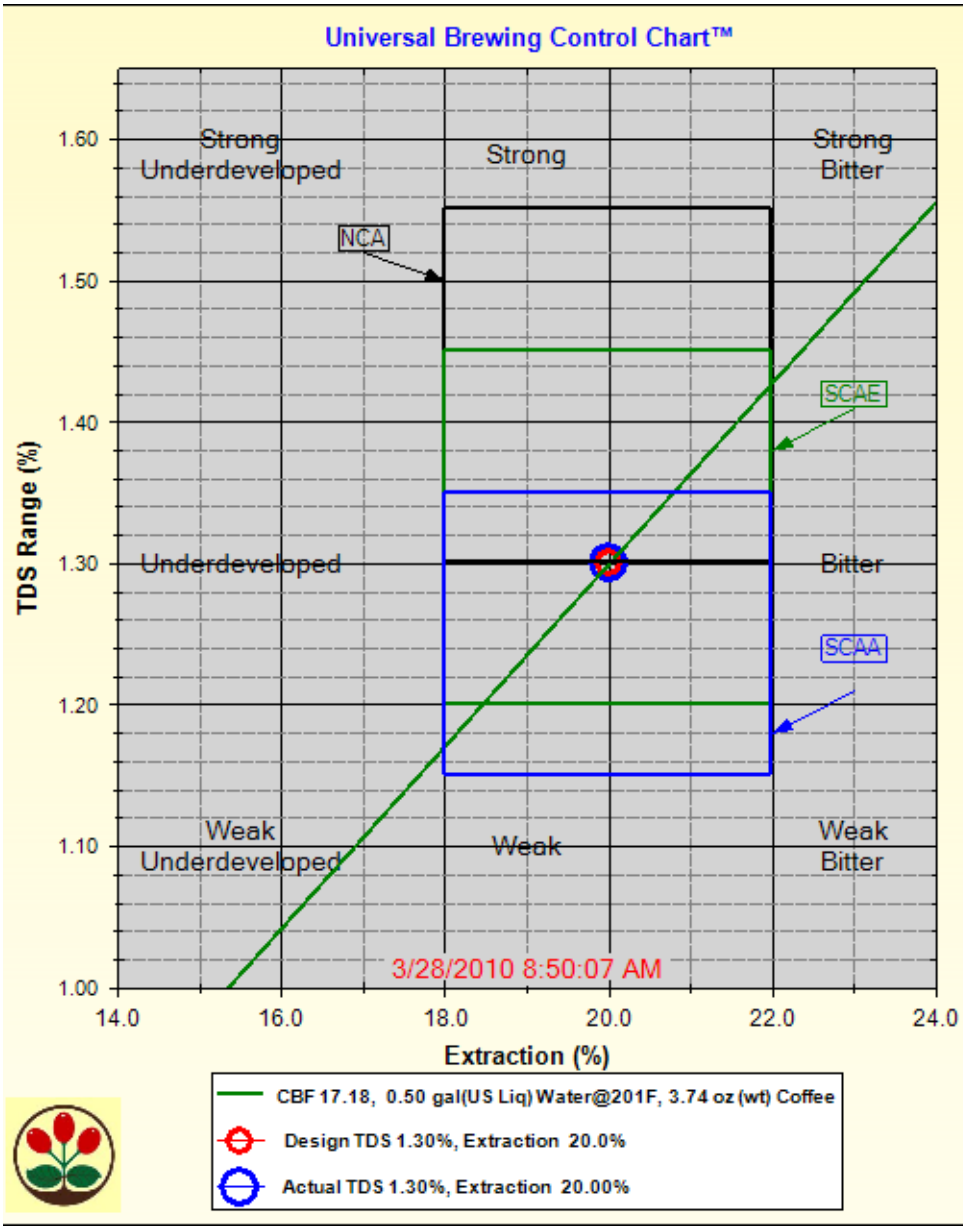
1. Select **Coffee** in the **RANGE** drop-down menu in the lower left-hand corner.
2. Enter the preferred Brew Water units in the drop-down next menu next to the Water Volume field, and enter the **Volume** in the Water Volume field.

3. Select the preferred **Strength TDS %** with the slider on the window's left-hand side. Extract**MoJo™** calculates the required **Ground Coffee weight** and final **Coffee Yield**, draws the brew formula line, and plots the target Strength TDS at the pre-set target extraction of 20% (see page 21).
4. Enter the preferred units of measure in the two calculated fields: **Coffee Yield** volume and **Ground Coffee** weight.
5. Continue reading in the next section: *Measuring Dissolved Solids*, page 40, and enter the measured % TDS in the Dissolved Solids Measurement field.
6. Use the File > Save menu selection to save the brew plan, and print if desired.

ExtractMojo™ for *Plan Coffee by Water Volume*



ExtractMojo™ Chart for *Plan Coffee by Water Volume*



In this example, Range has been set to **Coffee**, Brew water volume has been set to 0.50 Gallons, and **Strength** slider has been set to 1.30%. Extract**MoJo™** calculates the required ground coffee in oz-wt, and the brewed coffee yield in fl-oz volume. Brew temperature is same as start temperature.

HOW TO: **Design by Coffee Yield**

Traditionally, as in the previous example, brew formulas have been developed using a pre-set volume of brew water to develop a brew recipe. For example, a one (1) Gallon batch meant setting the brewer for one gallon of brew water, and using approximately 7.5 ounces coffee (i.e., the gold-cup standard for 1.3% TDS). However, this method results in a final yield of approximately 112-fluid ounces, leaving about 16-fl oz empty in the brewing vessel. In this mode, Extract**MoJo™** allows you to specify one (1) gallon of finished coffee to fill the vessel completely, and computes the exact portions of brew water and ground coffee required: 1.13 Gallons of brew water and 8.5 ounces of coffee.

Similarly, many brewers programmed in gallons may be used to brew into metric thermoses, or vice-versa. For example, often, a cafe will use 1.89 liters (one-half gallon) of brew water and 3.75 ounces of coffee to yield only 1.67 liters of finished coffee into a 2.5 liter thermos, leaving 0.83 liters of air in the thermos.

This design mode allows you to **specify the finished yield needed to fill your brewing thermos**, rather than leave a significant percentage empty. Units can be mixed in any combination (brew water in gallons, yield in liters), and Extract**MoJo™** calculates in the units specified. For example, 0.75 gallons brew water and 5.6 ounces of coffee will yield exactly 2.5 liters of finished coffee. To ensure accurate portions Extract**MoJo™** takes into account the water lost in the spent basket and the volume of water required as a function of temperature.

Use **Preferences** to set the mode to **Start by entering: Desired Coffee Yield**.

1. Set the *Range* pull-down menu [in the lower left-hand corner] to select the Coffee charting range.
2. Select the preferred units of measure in the drop-down menu next to the Desired Yield field, and enter the **Desired Yield** for the finished coffee.

3. Select the preferred units of measure [if necessary] for the two calculated fields: **Water Volume** and **Ground Coffee**. Note: Extract**MoJo™** calculates the required Brew **Water Volume** in Liters, and the **Ground Coffee** weight required in grams. **Start = Brew Temperature** is checked.
4. Select the preferred **Strength** with the slider on the window's left-hand side.
5. Continue in the next section: *Measuring Dissolved Solids*, page 40, and enter the measured % TDS in the Dissolved Solids Measurement field.
6. Use the File > Save menu selection to save the brew plan, and print if desired.

IMPORTANT Note about Design by Coffee Yield mode

This design mode facilitates better coffee brewing practice in the following ways:

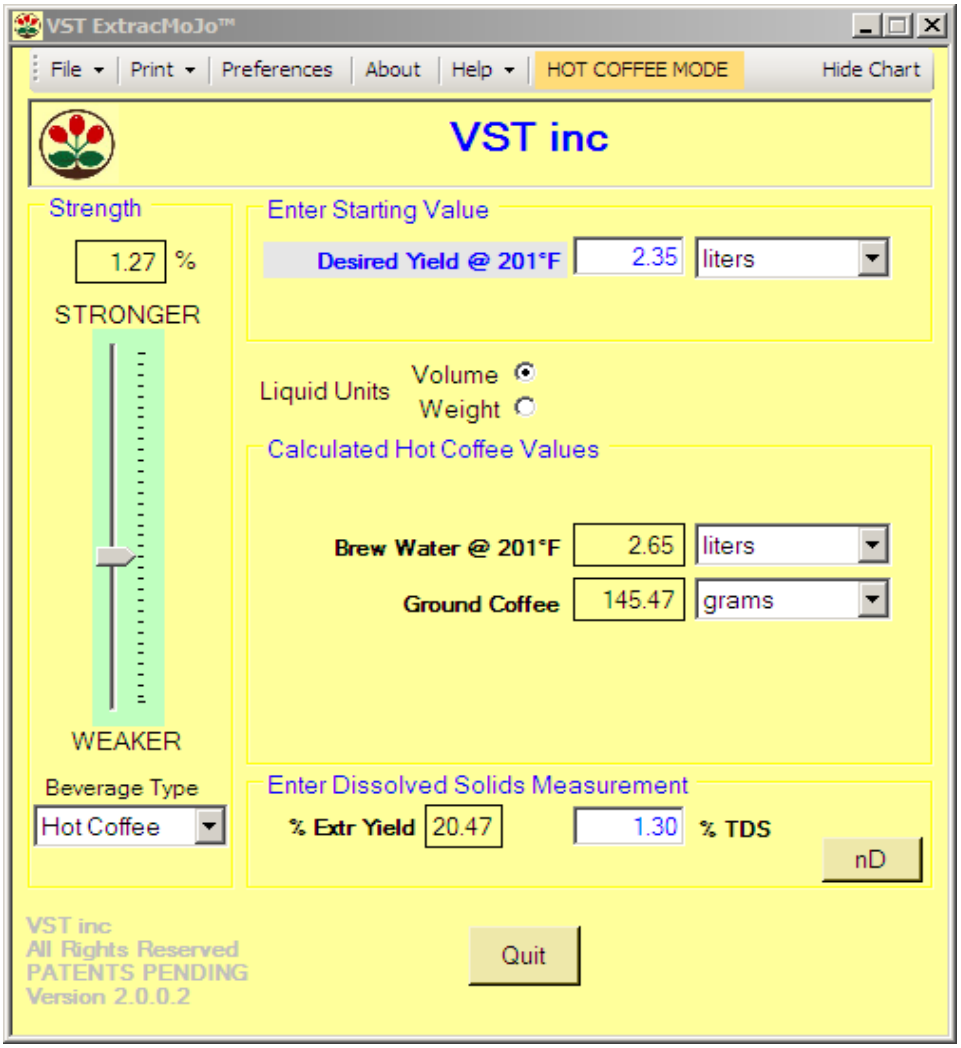
1. MoJo calculates the portions required to nearly fill the brewing vessel completely.
2. This mode reduces the amount of air in the thermos, and reduces the loss of aroma producing volatiles, while increasing the volume of hot coffee brewed. The additional thermal mass of coffee will keep the thermos hot longer, and can increase hold times by up to 10-15 minutes per batch.
3. Using this mode reduces the frequency of brewing, making your coffee brewing operation more efficient.
4. Brewing larger batches inherently reduces portioning errors.

In this example, **Range** has been set to **Coffee**, and **Desired Yield** has been set to 2.35 Liters for a 2.5 Liter Thermos. Strength slider has been set to 1.27% TDS. See page 22.

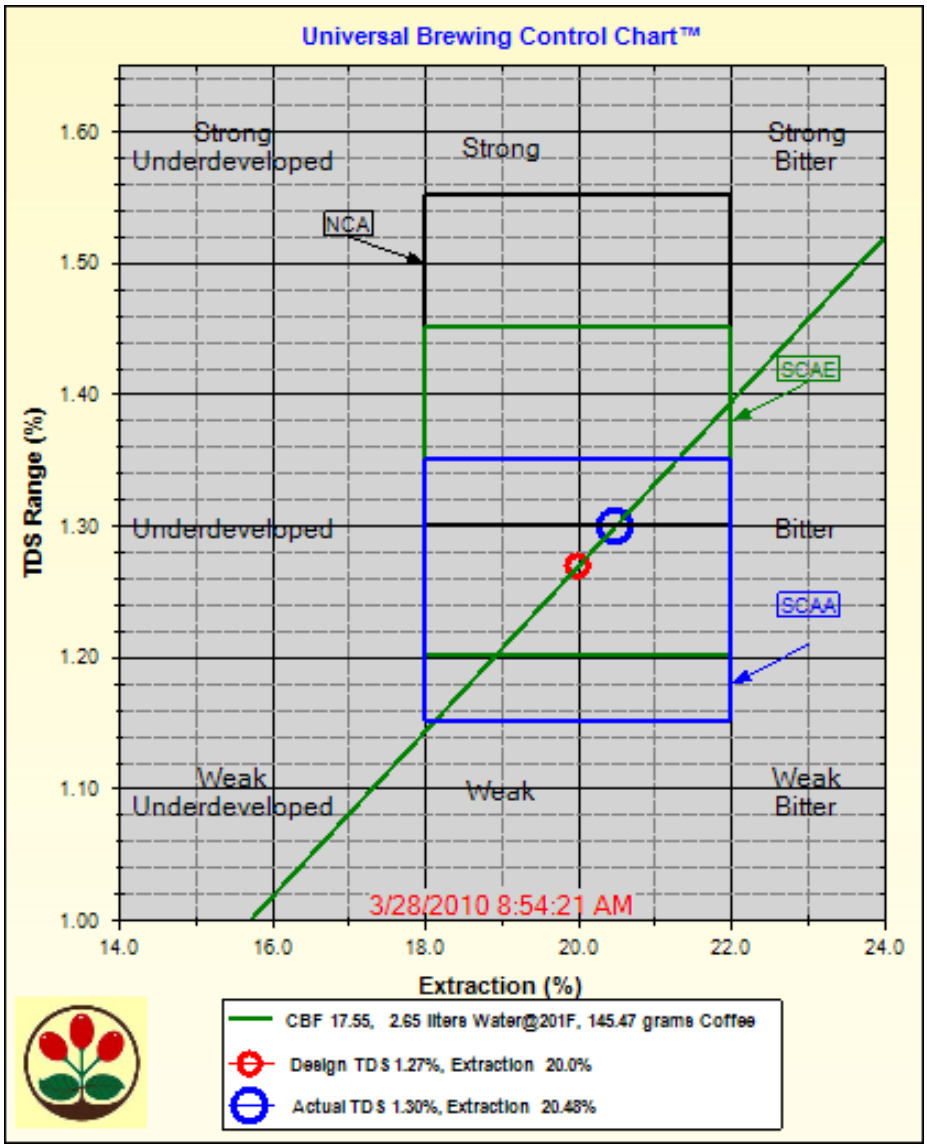
Dissolved Solids have been measured and entered at 1.3%.

Extract**MoJo™** draws Coffee Brewing Control Chart and plots both Design (red) and Measured (Blue) values on the Brew Formula line. Final recipe values are shown in the Chart Legend, at the bottom of the Chart Page.

ExtractMojo™ for *Design by Coffee Yield*



ExtractMojo™ Chart for *Design by Coffee Yield*



HOW TO: **Design by Ground Coffee**

Design by Ground Coffee Weight is a commonly used in high-volume feeder establishments using pre-measured, pre-ground pillow packs. While we never recommend pre-grinding your coffee, for freshness reasons, this mode is provided to address such establishments, in the hope they will learn how to improve their coffee program to internationally accepted standards, and then perhaps try some of their local roaster's coffee in the process.

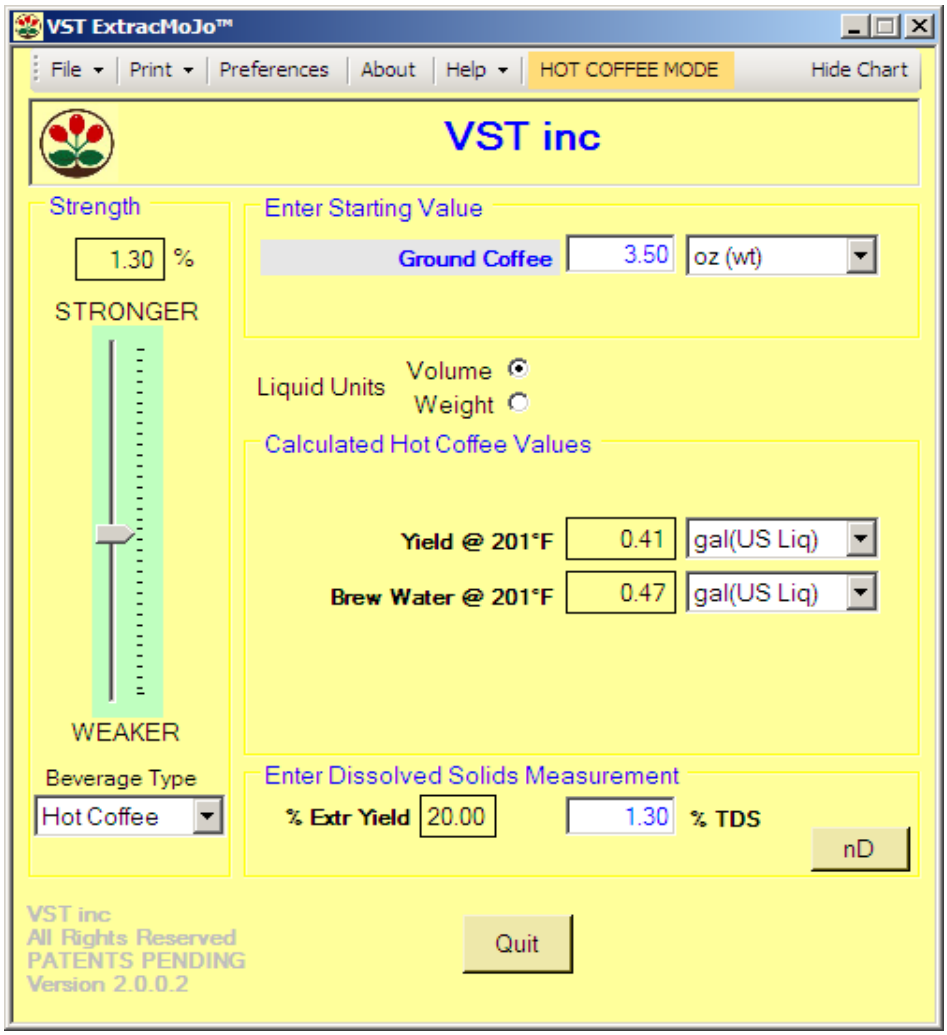
1. Select **Coffee** in the drop-down menu in the lower left-hand corner.
2. Select the preferred unit of measure in the drop-down menu next to the **Ground Coffee** field, and enter the weight in the **Ground Coffee** field.
3. Select the preferred units of measure if necessary for the two calculated fields: **Water Volume** and **Yield.** Extract**MoJo™** calculates the required brew **Water Volume**, and the final coffee **Yield** volume in units selected. **Start = Brew Temperature** is checked.
4. Select the preferred **Strength** with the slider on the window's left-hand side.
5. Continue reading in the next section: *Measuring Dissolved Solids*, page 40, and enter the measured % TDS in the Dissolved Solids Measurement field.
6. Use the File > Save menu selection to save the brew plan, and print if desired.

This example shows how to design to desired strength protocols using fixed ground coffee packets by weight. Extract**MoJo™** calculates the required brew **Water Volume** and **Yield** volume of coffee in the units selected.

Range has been set to **Coffee**. **Ground Coffee** has been set to the packet size of 3.5 ounces weight. **Strength** slider has been set to 1.30% TDS.

Dissolved Solids have been measured and entered at 1.3%

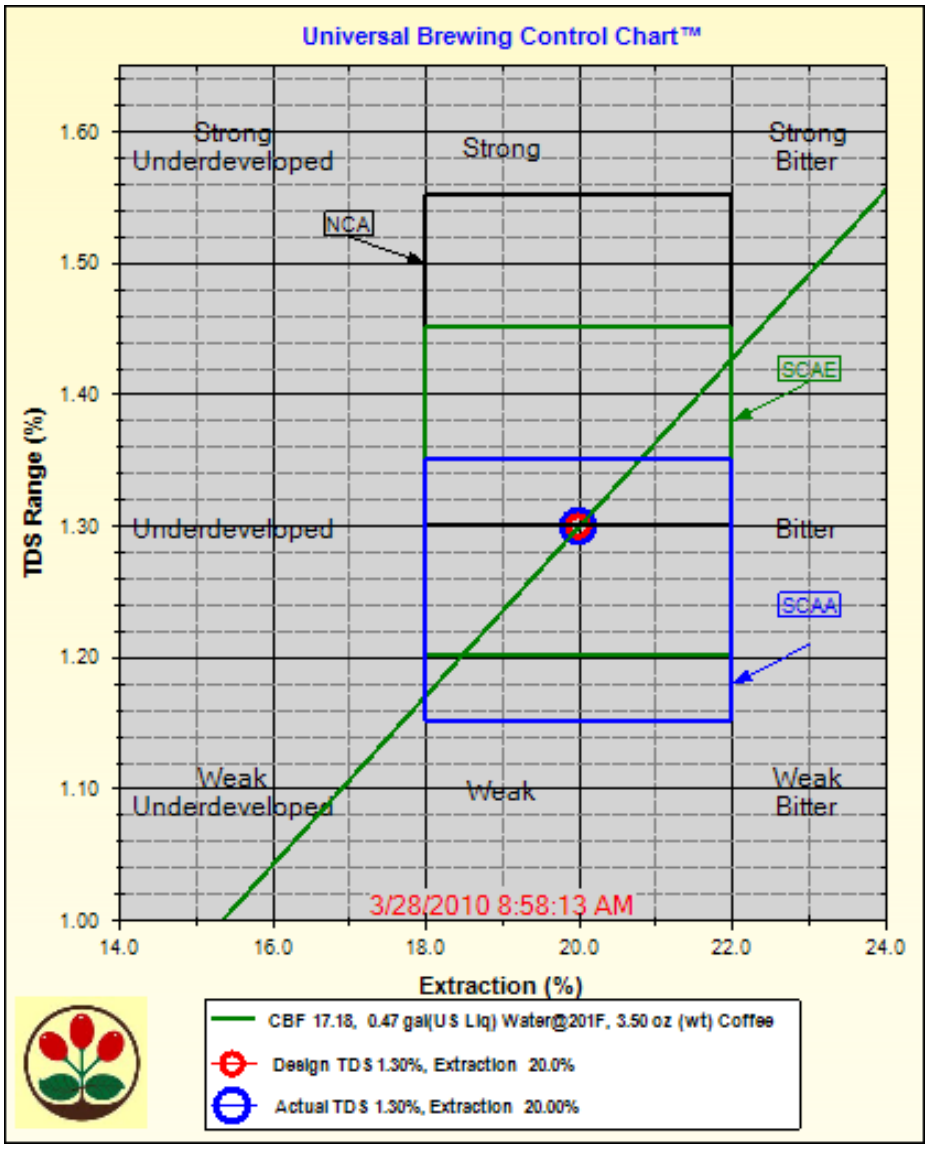
ExtractMojo™ for *Design by Ground Coffee*



Extract**MoJo™** draws Coffee Brewing Control Chart and plots both Design (red) and Measured (Blue) values on the Brew Formula line.

Final recipe values are shown in the Chart Legend, at the bottom of the Chart Page.

ExtractMojo™ Chart for *Design by Ground Coffee*



HOW TO: **Think About Iced Coffee**

The following section show an example of how to design for fresh brewed **Iced Coffee**.

Extract**MoJo™** will design coffee extraction protocols for Iced Coffee Concentrate, to be brewed fresh -- directly over ice. Extract**MoJo™** calculates coffee concentrate TDS strength both before and after ice is melted. The process is designed to allow approximately ninety-five percent of the ice to melt at brew completion time, so that the finished concentrate is cold, and ready to serve immediately after brewing. The complete brewing cycle takes only 5-6 minutes, typically.

Note: Care must be taken using this mode to choose portions that will not overload the brew basket. For example, a 0.5 - 1.0 gallon brewer may be able to brew 7 - 9 ounces of ground coffee, but could overflow the brew basket if more ground coffee is used. Generally, a 1.5 gallon brewer can accommodate up to 12-14 ounces ground coffee.

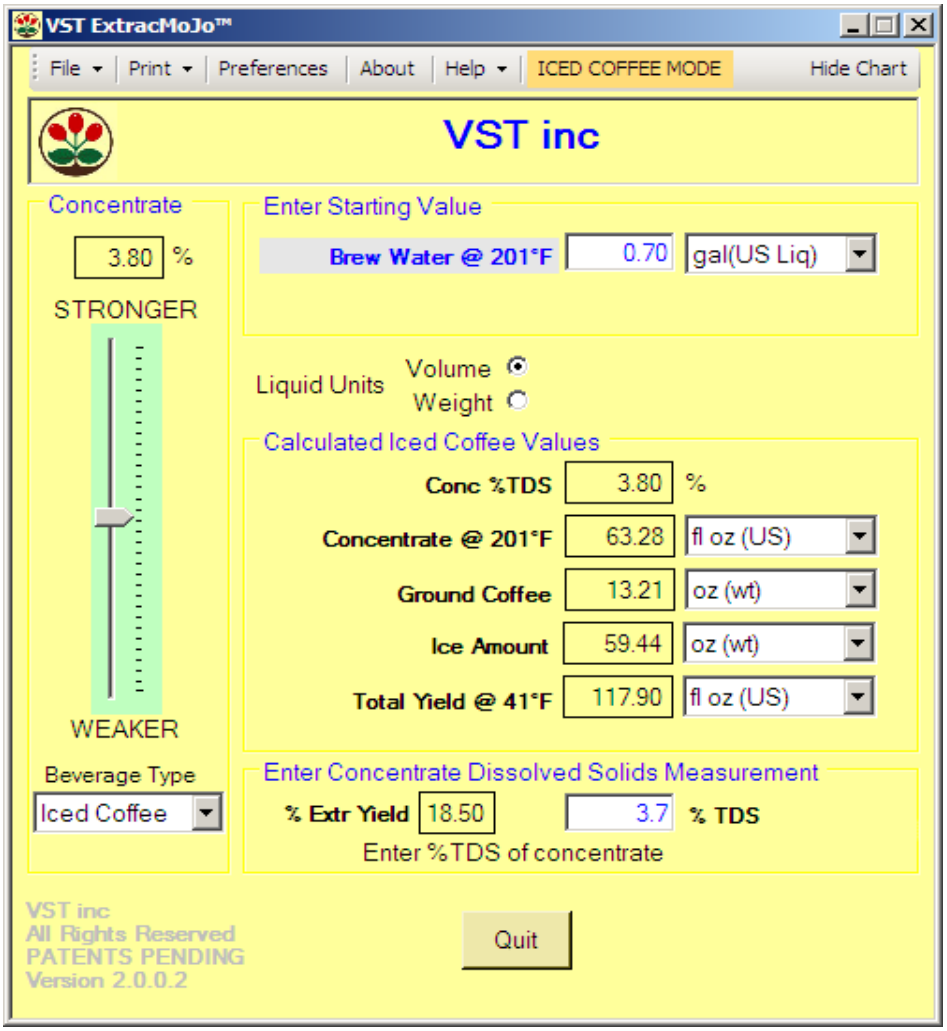
HOW TO: **Plan Iced Coffee by Water Volume with a 1.5 Gallon Brewer**

Extract**MoJo™** has been set up for a typical 1.5 gallon brewer. The brewer is programmed to dispense 0.7 gallons, yielding approximately a half-gallon of coffee at 3.7% TDS. The coffee is brewed into an open top container containing 62 ounces-weight of ice, then stirred and covered. The resulting concentrate is after serving over ice in a glass filled two-thirds will be about 1.5-1.8% TDS. Total concentrate yield is just under one gallon. This serves approximately sixteen 16-oz servings (7.5 fl oz concentrate over approximately 8 oz-wt ice).

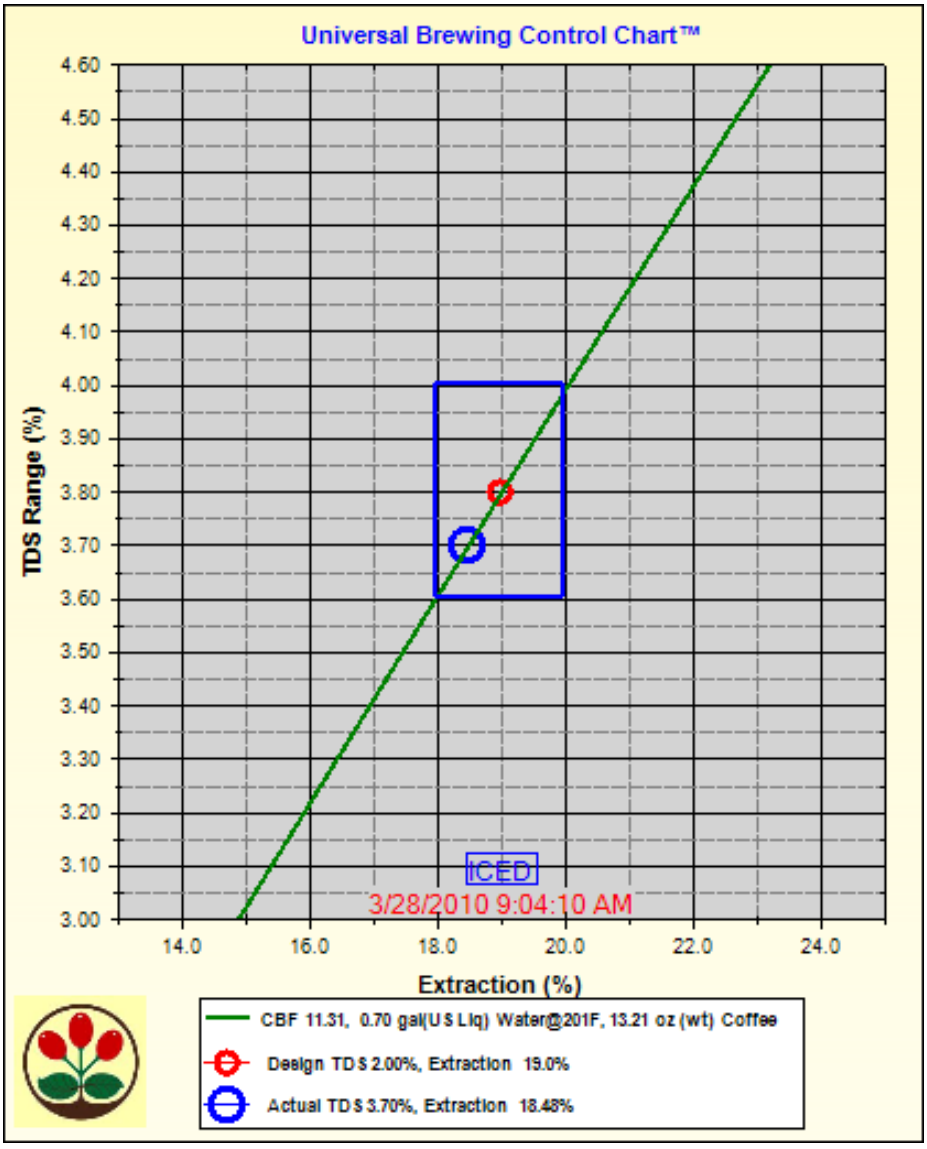
Examples of two other volumes are presented in the following reference sections:

- *How to: Plan Iced Coffee by Water Volume with a 0.5 Gallon Brewer,* page 57
- *How to: Plan Iced Coffee by Water Volume with a 1.0 Gallon Brewer,* page 60

ExtractMojo™ for *Plan Iced Coffee by Water Volume with a 1.5 Gallon Brewer*



ExtractMojo™ Chart *for Brewing Control Chart for approximately 1-Gal Yield of Iced Coffee Concentrate*



Espresso Mode

In a significant advance to the State-of-the-art of traditional espresso, ExtractMoJo now supports an advanced espresso mode, assisting professional baristas and specialty roasters to dial-in extraction yields without prolonged trial and error.

Extraction yield is the key to sweeter shots. Espresso is easily over-extracted into a bitter, highly acidic beverage, frequently unsuitable to serve. More common with larger doses above 14 grams, under-extracted espresso will taste sour and under-developed. Minute changes in grade of grind or pull time can cause significant changes in degree of extraction yield. Different baskets can cause significant changes to grade of grind, flow rates and extraction yield. It's not uncommon for a Barista to change several variables, such as dose, grade of grind, time (beverage volume), in an attempt to dial-in a shot, sometimes taking both time and efficiency away from busy operations at their cafes, as well as wasting expensive product.

Dial-in your shots in Espresso Mode

ExtractMoJo provides a simplified method of quickly determining your extraction yield, by setting coffee dose and beverage weights, and measuring % TDS (percent total dissolved solids), using a new Espresso Refractometer, and plotting the measurement on a new universal espresso brewing control chart to provide immediate and useful feedback showing graphically to what yield the shot has been extracted.

Using this information, the Barista can more quickly dial-in corrections to protocols -in the right direction- often nailing the shot in the second effort.

Using Extract Espresso Mode

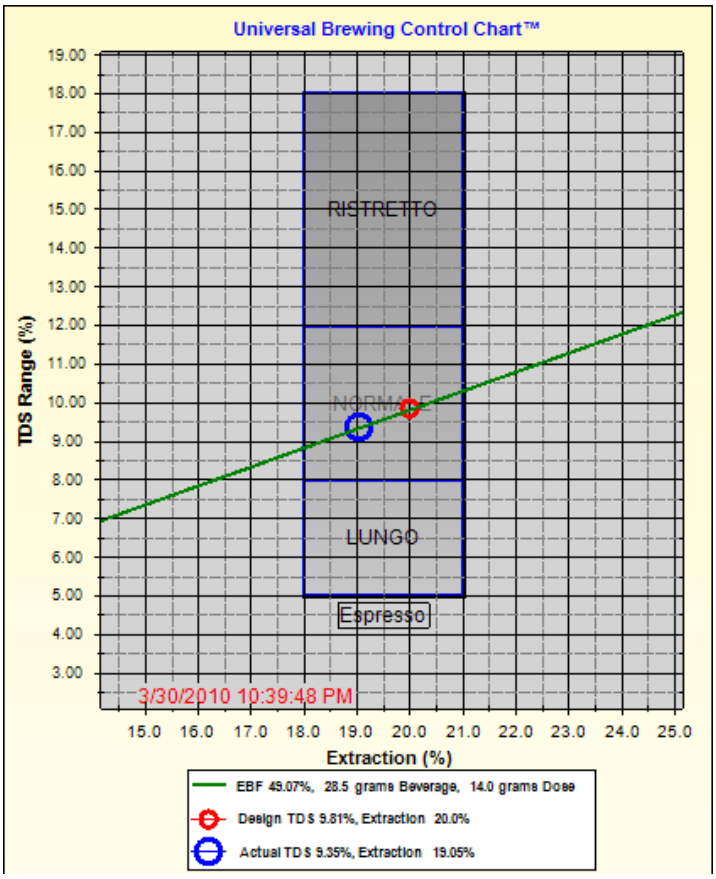
Setting Up

Select your basket size, and set dose to within a few tenths of a gram of the dose typically used. For example, using a double basket, dose 14.0 grams +/- 0.1 grams. For this example, we will try to pull a concentration of 10% TDS at 20% Extraction Yield. Using the Beverage slider, select the Beverage Weight necessary to achieve a 10% concentration at 20% Extraction Yield, or 28.0 grams.

Pull the Shot

Zero a gram scale with your espresso cup under the portafilter, and pull your shot, stopping the pump at approximately 26-27 grams, anticipating that your final weight will be ~28 grams. Now, reset the beverage slider to the actual beverage weight pulled, such as 28.5 grams for this example.

Espresso Mode Example 28.5 Grams



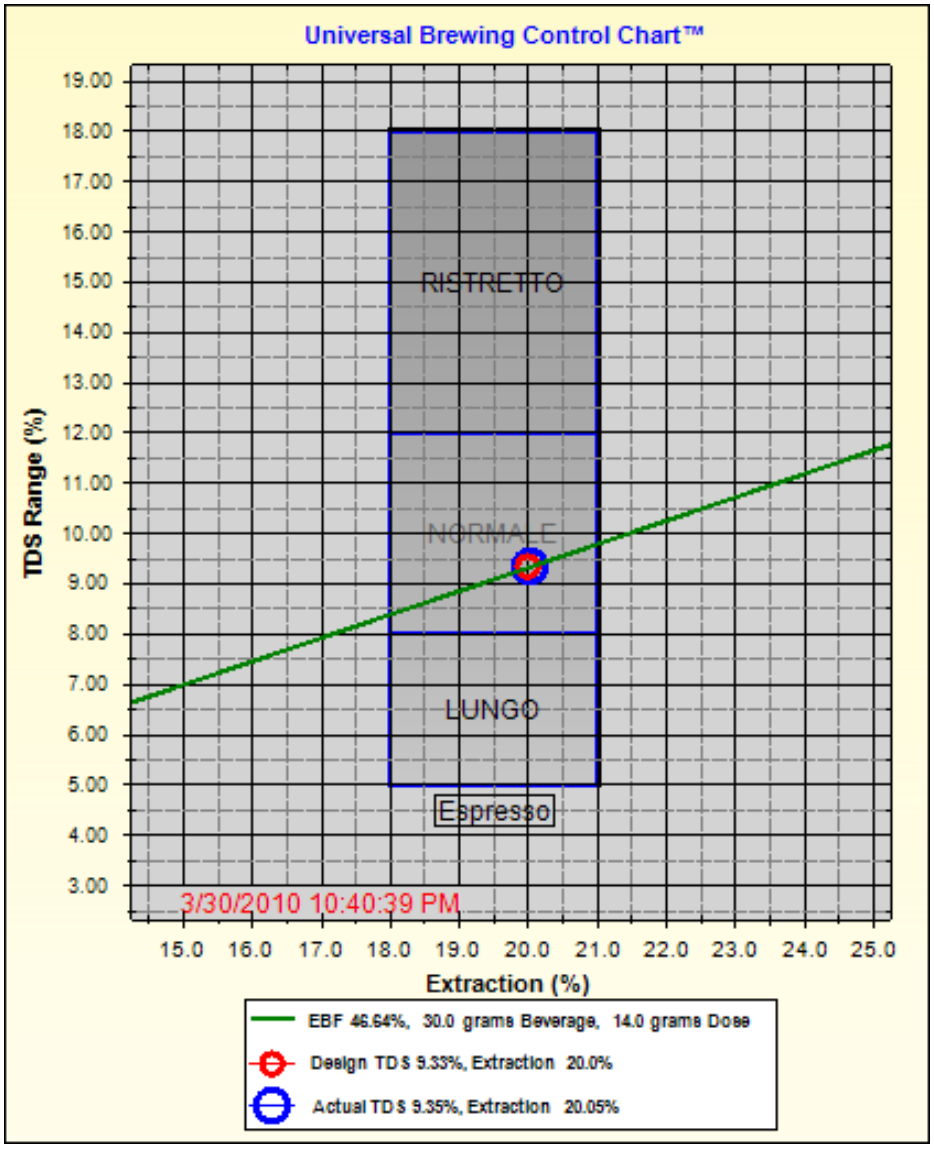
Making a Measurement of % TDS

Take a measurement of total dissolved solids using the Espresso Refractometer and enter the % TDS reading, 9.35% in this example, into the Brew Solids Measurement input box and press enter. ExtractMoJo plots the target (red) and measured actual (blue) result, in this case, extraction yield was 19%, very close to the target, and within an acceptable range to serve.

Make an Adjustment

Now, using the Beverage Weight slider, adjust the slider to "bulls-eye" the Blue and Red targets, and read the Beverage Weight. Note, the beverage weight being suggested is 30 grams.

Espresso Mode Example 30 Grams

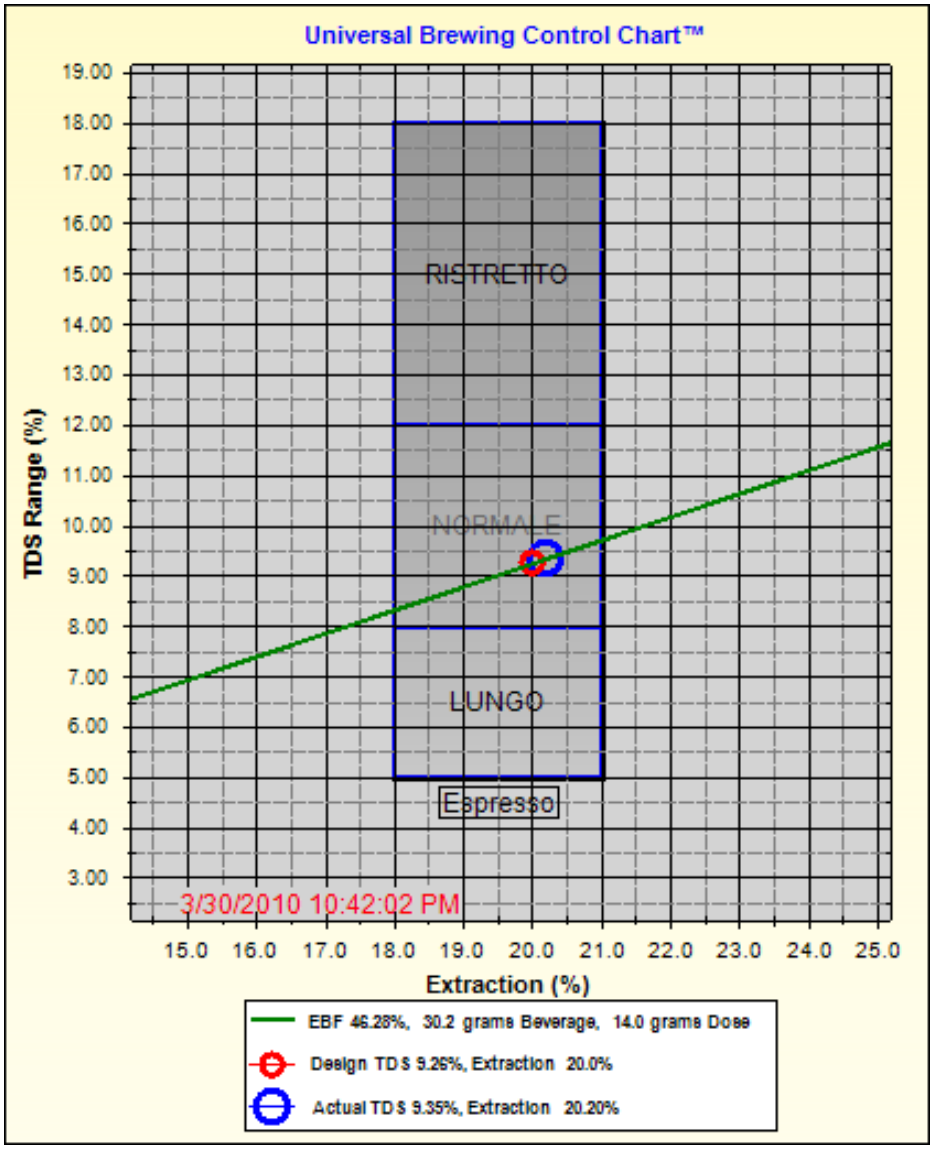


Without changing the settings on any of your grinder or espresso equipment, try pulling an additional 2 grams of beverage, and repeat the above measurements.

In this case, the second chart shows exactly the same condi-

tions, but with 30.2 grams of beverage pulled. Note the extraction yield shifted from 19.05% in the first pull to 20.2% in the second, and concentration dropped slightly to ~9.3%.

Espresso Mode Example 30.2 Grams



In most cases, if you are within 3-4% of the targeted Extraction Yield, you'll find the change in beverage weight suggested by

MoJo using this procedure will move extraction yield closer to the desired goal, and often very often within 0.5% of the targeted yield in the second effort.

Baskets

Baskets play a critical role in flow rates and extraction yield. Variations and defects in baskets are significant and very common, and can force grinder changes to adjust for improper hole sizes in your baskets. For example, a basket with holes too large will force a finer grade of grind to slow the flow. This increases sediment, and can lead to difficulties in over-extraction. A basket with holes that are too small will lead to coarser grades of grind for [apparent] proper shot times, and in general will lead to significant under-extraction and sour shots. If you're having trouble landing in the sweet spot (18-21% yield), try another basket, one that allows a different grade of grind. When you find a basket that provides a 10% concentration and 19-20% yield, with shot times in the range of ~24-34 seconds, mark the basket and try to sort out others that do not perform to a similar set of standards. Start using a 10% targeted concentration. After 19-20% yield has been achieved (at 10% TDS), then you can dial-in higher concentrations by simply reducing the beverage weights (all other things being left unchanged), to avoid abrupt changes to extraction yield.

In general, you should always be able to dial-in a sweet shot in the range of 19-20% extraction yield using a 50% espresso brew formula, that is 14g dose 28g beverage weight = 10% concentration at 20% yield. Similarly, a 20g dose and 40g beverage weight is also 10% concentration at 20% extraction yield.

Measuring Dissolved Solids

The **Coffee Refractometer** is an accurate and easily used hand-held instrument that gives you the TDS data needed to evaluate and record brew recipe results. The hand-held devices commonly in use before the introduction of the Coffee Refractometer were difficult to use, and they depended on a different technology that was less appropriate for the task.

Detailed information about refraction as method for analyzing coffee begins in the following section: *Coffee and Refractive Index*, page 62.

Refractometers and Temperature

The VST Coffee and Espresso Refractometers are temperature corrected. Each unit is tested for accuracy against a known standard and typically reads to an extrapolated accuracy of +/- 0.05% from 15-30 Deg C (although the warranted accuracy is +/-0.1%). This is accurate enough for most applications for coffee in the field. Higher accuracy refractometers for research and laboratory use are available at www.mojotogo.us.

Though the VST refractometers are temperature corrected, this does not mean that hot coffee should be placed on a cooler refractometer prism. Temperature correction means that the coffee sample and the instrument prism are stable at the same temperature, and in the temperature corrected range of 15 to 30 Deg C.

Maintaining Accuracy

In order to get the most accurate TDS measurements, one should calibrate the refractometer using deionized or distilled water stored at room temperature. The refractometer should also be stored at room temperature. Check the refractive index (nD) against a table for DI water at the temperature indicated when using the refractometer in its native mode (i.e., reading nD and TEMP). Then, cool the coffee sample to room temperature and transfer into the refractometer sample well, and allow time for the coffee sample and prism to reach the same temperature. Then take a reading.

Therefore, in order to obtain best accuracy, do not take the re-

fractometer out of your warm pocket or out of a cold car (in winter) and immediately expect it to work accurately. Allow time for the refractometer to reach ambient temperature and calibrate before use.

Using the VST Coffee Refractometer

When using the Coffee, and most other refractometers, the sample MUST be at the same temperature as the PRISM for an accurate measurement. Automatic Temperature Compensation (ATC) compensates for shifts in ambient temperature, not for the difference between coffee sample and prism temperature. Read the simple calibration and measurement technique sections, below, for an understanding of how to make accurate measurements.

Calibrate Using Distilled Water

Store the Refractometer and a container of distilled water at room temperature, and calibrate if there is a change in ambient temperature of more than a few degrees C. VST recommends calibration and use within a range of 15-30 Deg C, which should easily accommodate most "room temperature" conditions.

Measurement Technique

1. After brewing your coffee, be certain to stir the final solution before sampling.
2. Pour a few grams of coffee into a clean and DRY glass or porcelain cup, allowing the cups' mass to absorb thermal energy, and cool the sample. If necessary, transfer the sample into a second glass, and allow to cool.
3. When the sample has cooled to ambient temperature, transfer the sample to the refractometer sample well using a pipette. Use a few drops to completely cover the glass.
4. Leave the sample on the prism for 15-30 seconds before taking an initial reading. This allows the sample to acclimate to the temperature of the prism.
5. Check the sample a second time for a final reading.

Enter the Measurement

1. Enter the % **TDS** as read on the refractometer in the **Dissolved Solids Measurement** field, or if using a refractometer in the native nD and TEMP mode, click the nD button to enable the TDS calculator window. Enter the

refractive index and temperature, then hit Enter or TAB. The % TDS will be entered into the **Dissolved Solids Measurement** field automatically.

2. The Brew Result is plotted in blue.
3. Correct the brew protocol, if needed based on over- or under-extraction relative to the target. See Chapter 2, *Supplementary Information*, page 45.

When the brew is perfected, continue reading in *Saving your Brew Recipe*, page 43.

Saving your Brew Recipe

When the brew is perfected and you have entered the final data, you may complete the following steps.

1. Use the following commands to save the data to a permanent and stable location:
   - File > Save Data -- This saves a text file of the data in the window.
   - File > Save Plot -- This saves an image of the window including the chart. You can also right-click on the chart to select the option Save Image As, in which case please insure that the suffix (end of the file name after the dot) matches the file type selected.
2. You will be able to find the location where the data was last saved with the following command:
   - Recall Previous Data -- This command takes you to the folder where data was last stored.
3. You may want to make print a record of the brew to guide personnel and confirm the performance of equipment with the following commands:
   - Print > Print Chart
   - Print > Print Data
4. You can communicate your protocol to other sites with the following command:
   - File > eMail Data

2

Supplementary Information

The following sections provide technical and reference materials that cover the following topics:

1. Dealing with typical extraction problems often found in the field:
   - *Analysis of Typical Extraction Problems,* page 46
   - *Common Causes of Extraction Problems,* page 50
2. Some general background on water, water quality and water filtration recommendations:
   - *Water Facts,* page 54
3. Additional examples of brewing iced coffee for commonly available brewers:
   - *Additional Examples of Iced Coffee,* page 57
4. Some technical information regarding coffee and refractive index and the use of refractometers for coffee:
   - *Coffee and Refractive Index*, page 62
   - *Coffee Process Control and the importance of TDS in Quality*, page 63
   - *Refractometers and Temperature*, page 65
   - *More Information About Refraction and its Measurement*, page 66

Analysis of Typical Extraction Problems

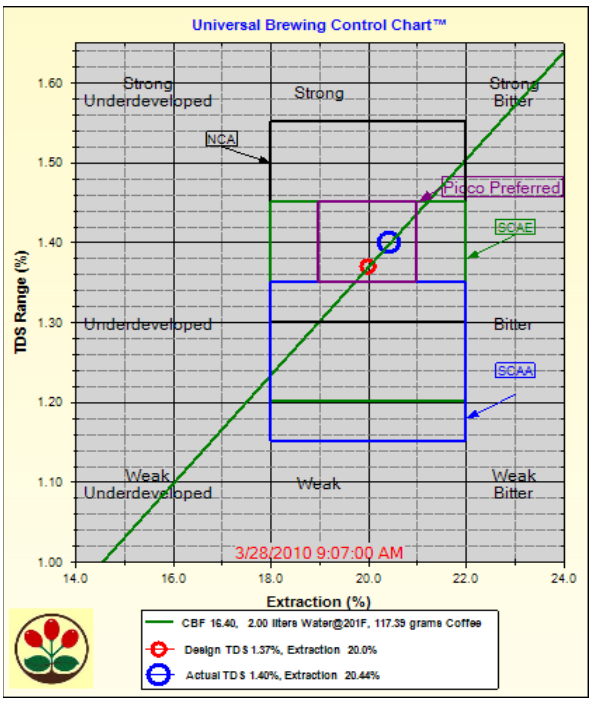
Coffee brewing techniques have gone largely unchanged for the past 50-60 years. Some new technologies have come and gone, but most would agree that when properly executed to gold cup standards, drip coffee can excel most other volume brewing methods For Those In Search of the Ultimate Cup™.

One of the most common problems in brewing quality coffee is that there has been no practical, field deployable method of designing extraction protocols and measuring actual results. This single fundamental issue has made consistency in quality virtually impossible to maintain.

The VST has developed some very exciting new technologies that are about to change how coffee is brewed in a remarkable way.

An example

Original Coffee Batch Design



This typical Boston café was set up with a preference for coffee brewed to 1.37 % TDS. The roast was a custom blend of coffees. The brew water volume was set and measured to 2.0 liters, and coffee was portioned out at 117 grams (brew formula ratio of 16.4:1).

The brewer was a standard FETCO CBS-2031e, the Grinder a BUNN G1, a gram scale for portion control.

After several months of superb coffee, and excellent customer

reports, the café began experiencing consistency problems with brewed coffee quality. Some batches were perfect, others tasted bitter, and unbalanced. The original batch design and measurement is seen in the Universal Brewing Control Chart™, above. The Red point shows the intended design target, the blue shows the actual %TDS measured using the Coffee Refractometer after initial set up.

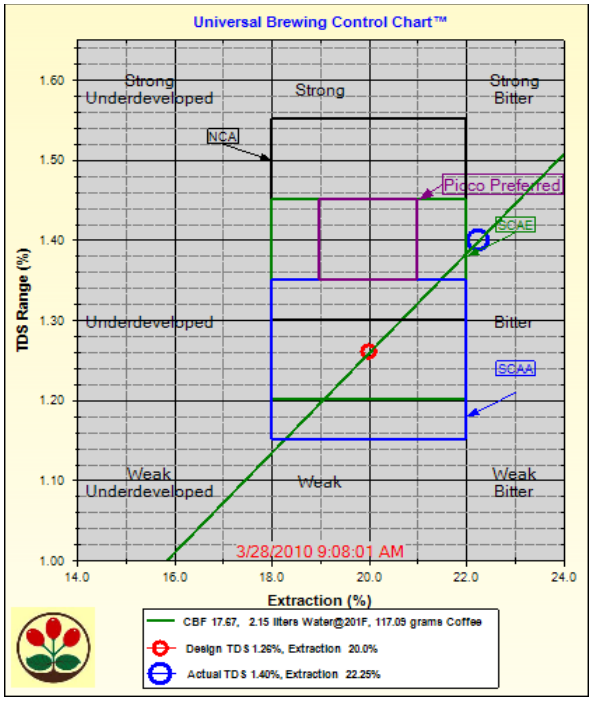
The same Café, coffee and equipment and setup is shown here, charted three months later. Clearly, there is a serious problem.

Problem Identification

The coffee weight was measured correctly at 117 grams;

Grade of grind was unchanged, and the grinder burrs were sharp;

Water filter was within allowable date and capacity range of use;



The brewer volume setting was unchanged, but was measured to be dosing 2.15 liters versus 2.00 as programmed, an 8% increase in brew water volume, changing the brew formula ratio to 17.7:1.

The chart shows the effect to the **brewing formula** ratio as a result of **water volume** error. **Note**: both the brew formula line and TDS design point have changed as a result of the volume error.

The additional 8% water volume had a secondary impact - by extending the brew time an additional 20-30 seconds to 06:00

(mm:ss). The net effect caused a change to the intended design TDS of 1.37 to 1.26 % and then over extracted to 1.4 % TDS. The coffee tasted exactly as the taste defect expected, exhibiting a slightly strong-bitter flavor.

The brewer was checked for programming volume and calibration changes, but all settings were confirmed as unchanged from the original setup. However, the brewer was clearly dosing 8% more water than the programmed setting.

Since the calibration and volume settings had not changed, and there were no filter problems, we measured the line pressure at the brewer water inlet. Line pressure to the brewer was measured over a period of 40-minutes, and fluctuated in a range from 48 to 68 psi. A sink nearby and icemakers, as well as other kitchen equipment and restroom demands within the cafe could be seen changing water pressure significantly.

Since water flow rate in the water line feeding the brewer (in GPM) is a function of supply line diameter (typically 3/8-inch) and line pressure, and the brewer uses time to dose the programmed water volume, and because the line pressure is unregulated, we initially concluded that these fluctuations were causing the observed variances in volume. However, the brewer is designed to use a gravity feed system from the top of the boiler to the shower-head, and should be virtually immune to line pressure fluctuations. An independent test proved this to be the case. We tested an identical brewer with 30psi and 50psi supply lines, and observed less than a 2% increase in volume at 50psi.

SOLUTION

The brewer had been fitted with a Bunn EQHP-10L filter, which includes a lime scale inhibitor. The Boston City water supply had a TDS of approximately 40-75ppm, and a hardness of just 1gpg (grain per gallon).

We discovered that the brewers' fill probe was unable to detect when the brewer was filled, because there were so few minerals in the water, after lime scale treatment, and because Boston's water was so low in TDS and hard minerals. As a result, the

brewer boiler tank was over-filling, and venting the excess water into the brew basket during brew cycles, when the fill valve was calling for water, but not shutting off when full.

FETCO technical support was contacted and their technicians suggested changing the sensitivity of the fill probe, using jumpers for selecting a more sensitive position on the brewer control board. In addition, since Boston's water supply is so low in TDS and hard minerals, we changed the filter to an EQHP-10 (without lime scale reduction) for future replacements.

After re-calibrating the brewer, we ran six cycles, each of which measured exactly 2.0 liters. Note: DO NOT USE a "bakers Cambro" for measuring liquid volume when calibrating a brewer, unless calibrated using a laboratory measuring vessel. Some Cambros use a silk-screened ink scale is rarely registered accurately. Use an accurate measuring container, and measure the water at the temperature brewed immediately after the brew cycle is completed, not after is has cooled.

All subsequent coffee brewed on the modified and re-calibrated brewer returned to the original design figure, above, and has maintained calibration since.

Additional Technical Information

Modern brewers, such as the Brew Wise series from Bunn include programmable refill sensitivity settings, and also calibrate in ounces-per-minute, for very accurate brew water volume dosing.

Common Causes of Extraction Problems

Extraction Versus Strength

Most readers at this point in the guide may not need a discussion of strength and extraction, as they are topics covered in much of the gold-cup standard programs and guides available from a number of sources, but for the purposes of completeness and to answer questions that may remain, we cover very general highlights here.

Extraction

Extraction is the percentage of the dry coffee by weight that is removed by dissolving in water during the brewing process. Up to 30% of the ground coffee by weight may be extracted. Most of the remaining 70% is cellulose, and is not soluble in water. Although 30% can be extracted, internationally recognized standards in quality coffee brewing set a target of 18-20% for extraction.

Our goal at VST is to control the brewing process such that not more than about 19-21 percent is extracted, depending on the particular coffee and whether it is being served hot or iced.

Over-extracting to more than these levels will extract many of the less desirable components of the remaining solids. These contribute significantly to those taste defects known as bitter, strong-bitter and weak bitter.

Under-extracting causes a taste defect that is under-developed and can be weak or strong under-developed. As coffee dissolves, the sweeter components dissolve first, and if the more bitter and acid elements do not have enough opportunity to join them, the coffee is unbalanced and not full-flavored.

Some coffees, such as certain African varietals, have very few of the acidic components contributing to bitter flavors, and as such can actually be extracted well beyond 20% without ill effect. Other coffees, such as certain high grown Colombians, have significant carbohydrate components that can be accentuated when slightly under-extracted, to emphasize the sugars when brewed as iced coffees. Extract**MoJo™** provides the tools necessary to navigate the brewing control chart to realize these

slight but important nuances.

Strength

Strength is simply the measured amount of solids extracted into the final coffee solution. Strength is usually expressed as the percentage total dissolved solids (% TDS). For example, for 100 grams of a coffee measuring 1.3% TDS, there are 98.7 grams of water, and 1.3 grams of dissolved coffee solids in solution.

As a simple example, let's estimate the % TDS, or strength, if we brew a batch using 1 liter of water and 56 grams of coffee, extracted to 20%. The final yield is ~888 ml of coffee solution, and we extracted 20% of 56 grams, or 11.2 grams in solution. The %TDS = 11.2/888 = 1.26%. Technically, we should convert the 888 ml of solution to weight, which is why we used the word *estimate.*

A batch of coffee using a fixed volume of water of 0.5 Gallons, to a desired strength of 1.3% and extracting to 20% requires 3.75 ounces of ground coffee. For a stronger batch, increasing the ground coffee to 4.0 ounces, and extracting to the same 20% will yield coffee that is 1.4% TDS in strength. More coffee is used, but is extracted to the same 20% level and yields stronger coffee, but it will still be sweet. One of the most common mistakes found at restaurants and cafes is a brew formula where coffee is too small in dose and too fine in grind, and is being over-extracted to a desired strength. The result is bitter coffee due to over-extraction.

A typical example might be a 2.0 liter Yield, using 2.23 liters of brew water and 109 grams of coffee. The finished % TDS measured 1.4, indicating a gross over-extraction to 25%. The grind was too fine, and the extraction time too long.

The key to quality to always adjust the grind, time (pre-wet + Pre-wet delay + brew time) and temperature to achieve extraction to 20% (+-) 1%.

Over-Extraction Common Causes

The following are some causes of over-extraction:

- Excessive extraction time, which could have several causes:
  - Too fine a setting for the grinder produces coffee that clogs the filter and slows flow causing increased dwell times.
  - Grinder burrs that are worn and or damaged will yield a wide range of particle sizes, including too many fines, causing extraction times beyond 5:45(mm:ss). A key method of identifying worn burrs is that changing to a coarser setting does NOT CHANGE THE EXTRACTION time, this can be ONLY corrected with new burrs.
  - Incorrect brewer dose timing. The brewer should be programmed to pre-wet the bed to approximately 8-14% of the total brew water volume. The brewer should be set to complete the brew cycle in roughly 5:00 - 5:40 seconds, for most light, medium and slightly dark roasted coffees. Program the brewer such that the total time from start of water to end of stream is approximately 5:20.
  - High water temperature.VST recommends 198-201 Deg F for most light-medium coffees, and 195-198 for dark roasted coffee.
  - Soft water. Water that lacking minerals causes fibers in filter paper and ground coffee swell abnormally, slowing extraction time causing over-extraction. DO NOT feed your coffee brewer with softened water, or from a filter system intended for an espresso machine. See WATER section for recommended filtering techniques for coffee.
  - Incorrect pH. Water should ideally be from 7.0-7.2. Water below 7.0 risks contamination from lead and copper etched from plumbing pipes and fixtures.

Under-Extraction

The following are some causes of under-extraction:

- Coarse grind allows water to run through too rapidly and presents less surface area to the water which prevents coffee solids from dissolving.
- Too short extraction time. General rule of thumb, ideal extraction to 20% takes approximately 5:00-5:30 for drip coffee at the proper grade of grind and temperature, 4:00-4:30 for French Press coffee.
- Insufficient pre-wet. VST recommends from 8-14% pre-wet, with the higher end of that range used for larger doses of coffee, and lower for smaller doses.
- The filter paper in a brewer was not pressed against the walls of its holder, allowing water to BYPASS the coffee. Most brewer manufacturers offer basket clips to solve this problem. It is especially in issue with smaller batches in deeper baskets. When brewing a smaller batch, be certain to dress the filter paper flat against the sides of the basket around its complete circumference.
- Low water temperature.
- Very hard water. See reference section on Water, *Water Facts*, page 54.

Water Facts

Minerals and other elements and compounds in water can taint taste as well as influence extraction and affect equipment. Your coffee is 98.5% water, so you should always study technical details about the source. If a public water supply, the measured results can usually be obtained from the local water district resources managing authority. Know your water, so you can treat it if necessary, and with the proper solution for coffee, espresso, tea, ice making equipment, all of which require different solutions.

Water TDS and Coffee

The TDS of water includes all dissolved solids, of which certain minerals are a subset, referred to as water hardness. Some minerals are desired in water used to brew coffee, for best flavor, and for proper extraction, generally about 75-150ppm is considered desirable for coffee.

Desirable Water Parameters for Coffee Brewing		
Parameter	Ideal Range	Needs Correction
TDS	75-150ppm	below 50, above 300
Hardness	17-120ppm	below 17, above 120
Grains per Gallon	1-7 gpg	below 1, above 7
Iron	0	above 0
Manganese	0	above 0
Chlorinates	0	above 0

Modern water filter systems for commercial use include three-media systems designed to treat water for brewed coffee and tea for reduced sediment and chlorine taste and odor. The filters allow some dissolved solids to remain, and are not considered softeners. These filter systems include:

• A multi-zone pharmaceutical grade pleated nylon pre-filter for particle reduction to 0.2 to 1.0 microns.

• Reduced scale formation by the controlled release of scale inhibitors. Note: DO NOT USE a lime scale inhibitor if TDS is ≤50ppm and Hardness is ≤ 1gpg (17.1ppm).

• Carbon block media for chlorine taste and odor.

The filters are generally available in sizes rated to treat from 10,000 to 34,000 gallons before needing to be replaced, so are effective and economical to use, and are highly recommended. The cartridges fit into standard heads that include an automatic pressure vent and shut-off to facilitate fast and easy replacement. We recommend plumbing these into EVERY brewer installation, with a flush bypass on the filter output.

Note about ExtractMoJo™ and TDS measurements

Note: The VST Extract**MoJo™** system and Coffee Refractometer assumes the use of water having less than 300ppm of total dissolved solids, and pH levels within a range of 6.8-7.8.

Water Hardness and Espresso Machines

Water Hardness is a common quality of water which contains dissolved compounds of calcium, magnesium, and sometimes other elements. Hardness can typically cause the buildup of scale inside brewers, and especially espresso machines. Lime, is a principle cause of hard water. Lime can quickly create scaling that is difficult to remove. You can reduce the hardness of water through many commercially available treatments.

Dissolved calcium and magnesium salts are primarily responsible for most scaling in pipes and heaters and cause numerous problems in coffee equipment boilers, espresso boilers and espresso steam boilers. Untreated water in excess of 7 grains per gallon can cause thousands of dollars in damage to an espresso machine in a matter of months. All espresso machine water supplies above 1 grain per gallon should be treated for water hardness.

Hardness is usually expressed in grains per gallon or ppm as calcium carbonate equivalent. The degree of hardness standard as established by the American Society of Agricultural Engineers (S-339) and the Water Quality Association (WQA) is shown in the table below:

Term	Grains/Gallon	Mg/Liter (ppm)
Soft	Less than 1.0	Less than 17.1
Slightly Hard	1.0 to 3.5	17.1 to 60
Moderately Hard	3.5 to 7.0	60 to 120
Hard	7.0 to 10.5	120 to 180
Very hard	10.5 and above	180 and above

Filters must be changed after a certain volume of water passes through them. For espresso machines, water softening filters often express capacity in grains. To determine when a softener cartridge must be changed, estimate the amount of water used, or use a water flowmeter that measures in gallons, and simply divide the filter capacity in GRAINS by grains per gallon of your water supply. The result is the number of gallons that cartridge will treat before its medium becomes saturated.

Additional Examples of Iced Coffee

This chapter includes information on How to: Brew Iced Coffee on 0.5 and 1.0 Gallon Brewers:

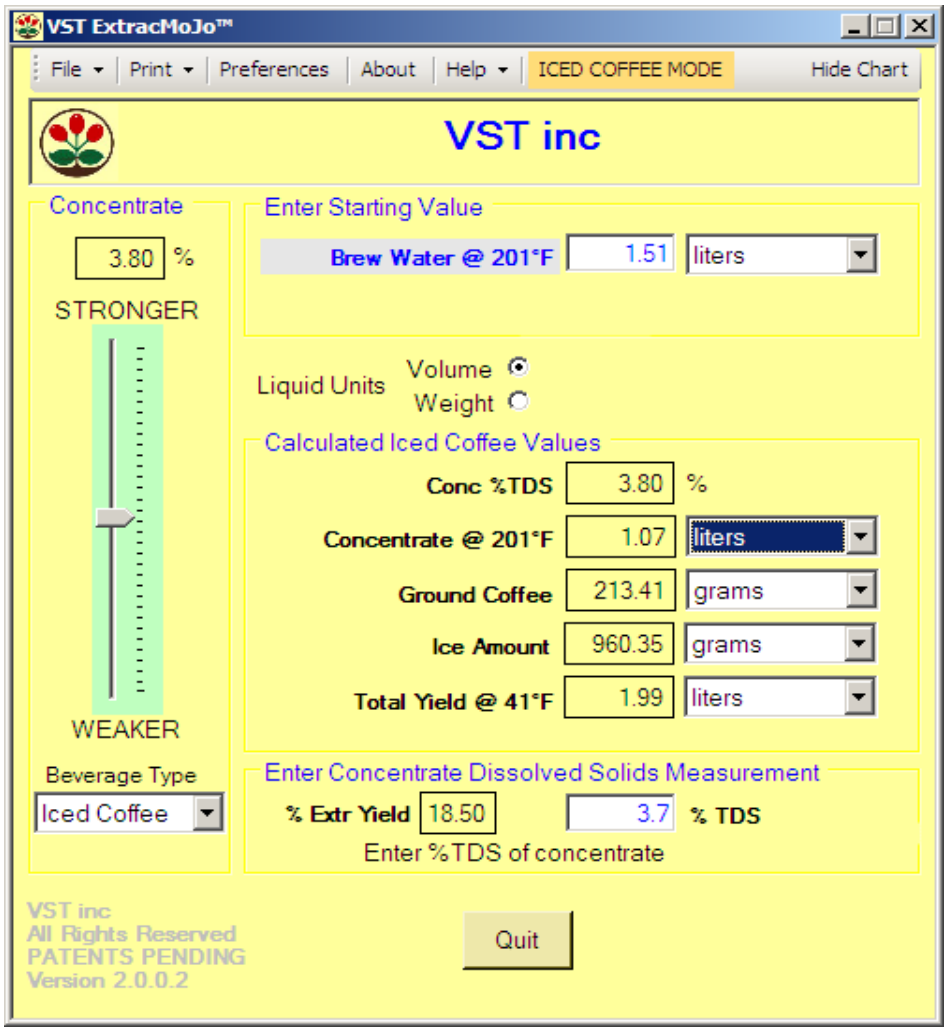
HOW TO: Plan Iced Coffee by Water Volume with a 0.5 Gallon Brewer

In this example, Extract**MoJo™** has been set up for a typical 0.5 gallon brewer. The brewer is programmed to dispense 1.51 liters, using 213 grams of coffee, and yielding approximately 1.07 liters of coffee at 3.8% TDS. The coffee is brewed into an open top container containing 1,000 grams-weight of ice, then stirred and covered. Total concentrate yield is 2.0 liters. This serves approximately nine 16-oz servings (7.5 fl oz concentrate over approximately 8 oz-wt ice).

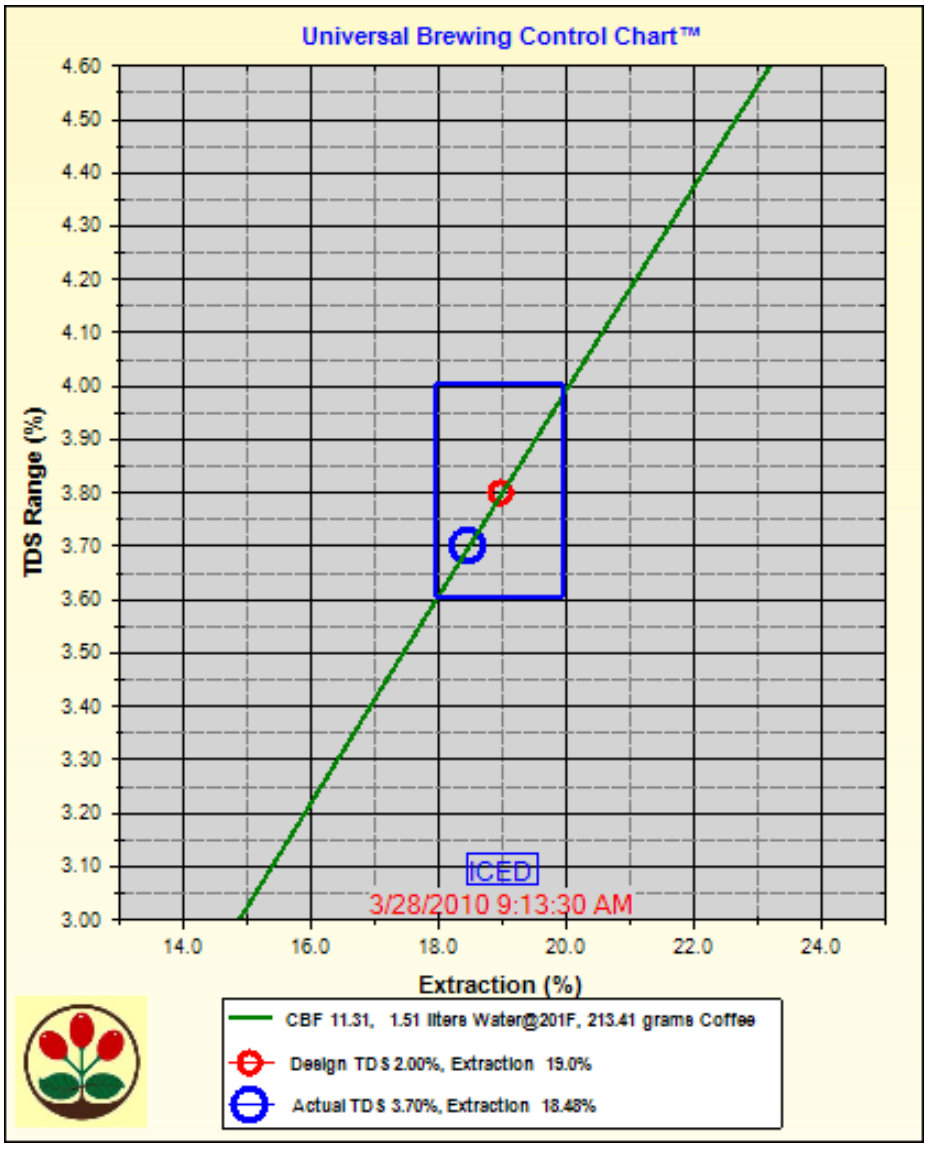
> *Note:* Brewing ICED Coffee requires the maximum weight of coffee the brewer basket is designed to hold. Therefore, Pre-Wet must be used to ensure an even, complete extraction. We have found that 12-15% (Pre-Wet Volume) of the brew water volume must be Pre-Wet for 40-50 seconds (Pre-Wet Delay), in order to obtain a proper extraction.

When measuring the ICE to be used for the brew concentrate, weigh the initial batch, then use a marker to mark the height of ICE in brewing vessel so that volume can be used for ICE measurements for subsequent batches.

ExtractMojo™ for *Plan Iced Coffee by Water Volume with a 0.5 Gallon Brewer*



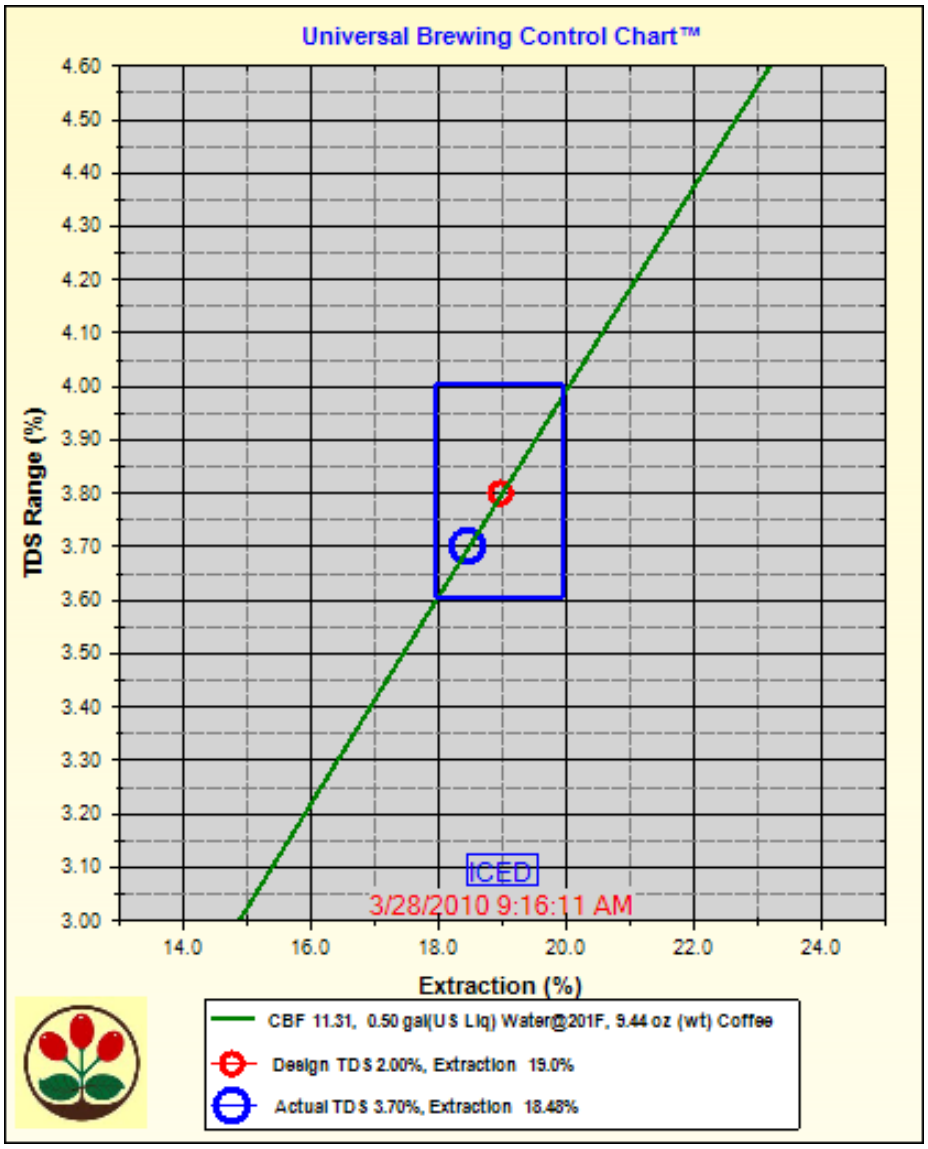
ExtractMojo™ Chart for *Plan Iced Coffee by Water Volume with a 0.5 Gallon Brewer*



HOW TO: Plan Iced Coffee by Water Volume with a 1.0 Gallon Brewer

In this example, Extract**MoJo™** has been set up for a typical 1.0 gallon brewer. The brewer is programmed to dispense 0.50 gallons of water, using 9.4 ounces of coffee, yielding approximately one-third gallon of coffee concentrate at 3.8% TDS. The coffee is brewed into an open top container containing 44 ounces-weight of ice, then stirred and covered. Total concentrate yield is about 3/4 gallon. This serves approximately twelve 16-oz servings (7.5 fl oz concentrate over approximately 8 oz-wt ice).

ExtractMojo™ for *Plan Iced Coffee by Water Volume with a 1.0 Gallon Brewer*



Coffee and Refractive Index

Refractive Index measurements have been used for process control in the food industry since the 1940's. Typical measurements are usually for sugars in fruits, such as melons, orange and other juices, sugar content in grapes for the wine industry and many other examples. Refractive Index is directly related to the Total Dissolved Solids in solution of Coffee. To the best of our knowledge, no one has ever provided an easy to use, accurate and portable refractive index device calibrated specifically for coffees.

Previous methods for TDS measurement of coffee include the oven drying **dehydration metho**d, which is slow and expensive but highly accurate, **conductivity instruments** which are difficult to calibrate and have proven unreliable and the **hydrometer method**, which is delicate, temperature sensitive and impractical in most environments.

To provide a meaningful solution to this problem, VST has partnered with a world leading manufacturer of optical instruments to develop a state-of-the-art **refractometer designed specifically for coffee**, called the **VST-Coffee Refractometer** manufactured by Reichert Analytical Instruments. Reichert is a well known optical instrument manufacturer, and their products have won technical achievement awards for their innovative design, accuracy and practical use in the field for hundreds of applications.

Coffee Process Control and the importance of TDS in Quality

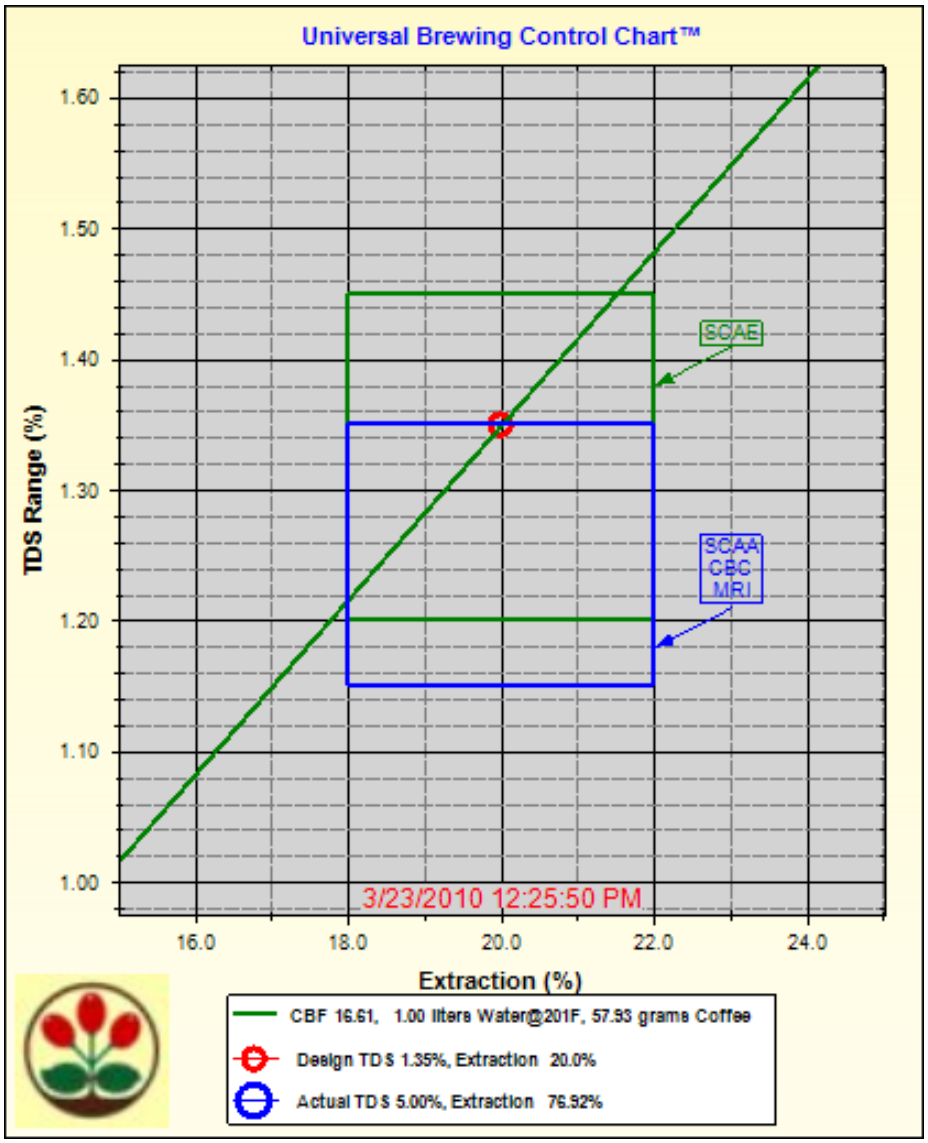
Internationally accepted quality standards in the specialty coffee industry established [in the 1950's] that extraction of approximately 20% by weight of the ground coffee will achieve the best quality brewed coffee, using various brew methods. The precise extraction percent may be varied for particular coffees, along with the strength, to achieve finely tuned recipes for particular coffee cultivars, growing regions, climate, a.k.a.,terroir, and roast characteristics.

Up to 30% of the available soluble solids in [ground] coffee can be extracted, with most of the remaining 70% being cellulose, and not soluble in water. However, generally speaking, extracting more than 21% will begin to sharply increase those components in coffee that contribute to bitter taste defects associated with over-extraction. Extracting less than 18% is generally associated with weak, under-developed taste defects.

In order to determine the **actual level of extraction** reached for a particular coffee batch, one must know the brew formula and the soluble solids in final solution, or Total Dissolved Solids (% TDS). The brew formula is simply the water amount by weight, and the ground coffee weight used in the batch.

The **Brew Formula** is expressed as a curve on a brewing control chart, seen as the green line in the following graphic. The **TDS** is measured using the VST-Coffee Refractometer at 1.30%, and plotted on the Brew Formula line in red. The **percent extraction** can then be read directly off the chart. In the following graphic, the extraction in this design example is exactly 20%.

Another way of expressing this example is that 20% of 58 grams of coffee, or about 11.6 grams of coffee were extracted and dissolved into approximately 858 grams solution, or about 1.35% soluble solids in solution.


Universal Brewing Control Chart™
TDS Range (%)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
SCAE
SCAA
CBC
MRI
3/23/2010 12:25:50 PM
16.0
18.0
20.0
22.0
24.0
Extraction (%)
CBF 16.61, 1.00 liters Water@201F, 57.53 grams Coffee
Design TDS 1.35%, Extraction 20.0%
Actual TDS 5.00%, Extraction 76.92%

Refractometers and Temperature

The VST Coffee refractometer is temperature corrected. Each unit is tested for accuracy against a known standard and typically reads to an extrapolated accuracy of +/- 0.05% from 15-30 Deg C (although the warranted accuracy is +/-0.1%). This is accurate enough for most applications for coffee in the field. Higher accuracy refractometers for research and laboratory use are available at at www.mojotogo.us.

Though temperature corrected, this does not mean that hot coffee placed on a cooler refractometer prism. Temperature correction means that the coffee sample and the instrument prism are stable at the same temperature, and in the temperature corrected range of 15 to 30 Deg C.

The procedures for calibrating and using the Coffee Refractometer appear in the following section: *Measuring Dissolved Solids*, page 40.

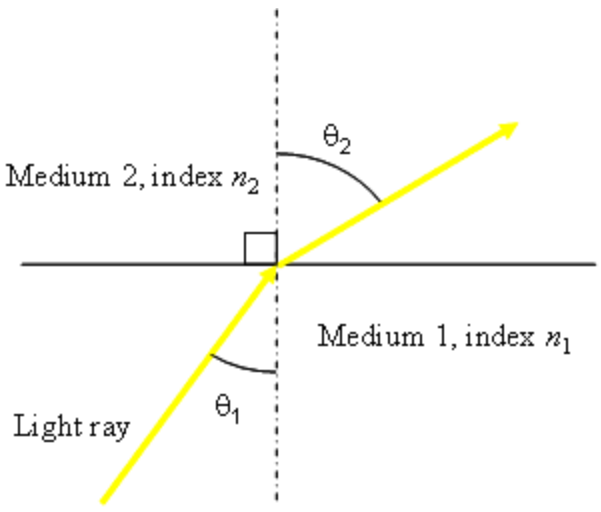
More Information About Refraction and its Measurement

The following sections explain the science and instruments related to measuring refraction:

What is Refractive Index?

Refractive index is a property of any substance that affects the velocity that light propagates through it. From a practical standpoint, we see the effect of refractive index in the form of a beam of light bending as it traverses the interface between two mediums such as air and water. For this reason a straw looks like it bends when placed in a glass of water. As an illustration of the bending of light, consider the ray in the following graphic propagating at an angle of q1 in Medium 1 which has an index of refraction of n1. This ray bends to an angle of q2 as it passes into a Medium 2 of index of refraction n2. The mathematics that describes this amount of bending are given by Snell's Law according to Equation (1):

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$



Manipulating Equation (1), one finds that the refracted beam in

Medium 2 travels at an angle q2 according to Equation (2):

$$\theta_2 = \arcsin\left(\frac{n_1 \sin \theta_1}{n_2}\right)$$

Therefore, the larger n1 and q1 are and the smaller n2 is, the larger q2 becomes.

It should be noted that the index of refraction for all material changes with wavelength. In other words, the index of refraction of glass, water, coffee, or any other material is different (actually higher) for blue light than it is for red light. It is for this reason that water droplets in the sky create a rainbow from sunlight and that sunlight passing through the beveled glass of a window or through chandelier glass will create a spectrum of colors on the wall or floor of a room.

What is a Refractometer?

A refractometer is an instrument designed to measure the index of refraction of a sample of material such as coffee, water, glucose, or other liquid or gel. Since the index of refraction of any material changes as a function of the wavelength of light, refractometers generally measure the index of refraction of light at a wavelength close to 589.3 nm, which is yellow light.[1]

In the food industry, refractometers are used to measure solution concentrations, where these solutions can include soft drinks, fruit juices, tea, and coffee. For any of these solutions, as more material (sugar or other solids) are added to water, the index of refraction increases. By correlating how the percent solids for a particular solution changes the index of refraction, the measurement of index of refraction can later be used to determine the percent solids or TDS in a given solution.

Refractive Index and Brix

Note that in the food industry, it is common to refer to the degree Brix of a given solution. Strictly speaking the º Brix is only

[1] Historically yellow light of a wavelength of 589 nm is used because before lasers were invented, scientists could generate such pure yellow light using a sodium arc lamp. These yellow lamps are sometimes seen today to illuminate parking lots or alleys at night.

accurate for a solution composed of only sugar and water, as it is a measure of the percent sugar by weight in a sugar-water solution (for example, a solution with 10 gm sugar and 90 gm water is a 10% sugar solution and therefore a 10 º Brix solution).

The term Brix has been replaced with the more modern "Mass Fraction" meaning g/100g.

For solutions other than sucrose in water, a separate correlation to a known set of standards is required. VST has performed a correlation for both Coffee and Espresso, so that a true Mass Fraction expressed as percent Total Dissolved Solids can be obtained for a wide range of roast styles ranging from light to medium and slightly darker roasts through, for example, Style Roasts.

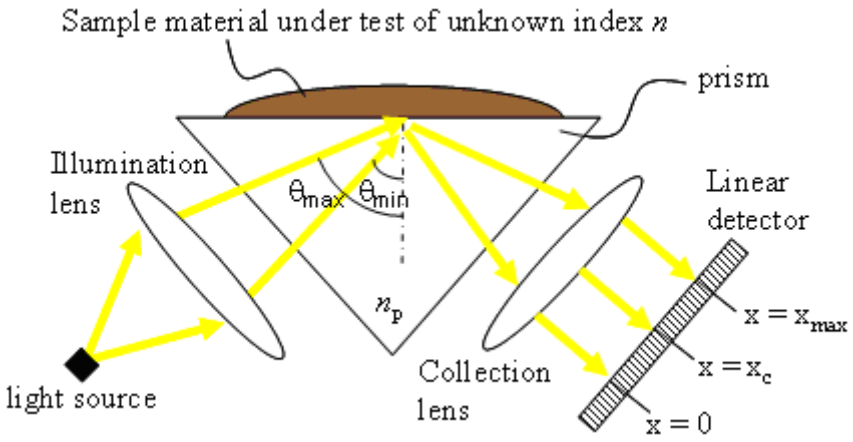
When measuring espresso, or any coffee brewed with a metal screen, the preparation must be filtered first to remove suspended brew solids in order to obtain a true dissolved solids measurement. This is easily accomplished with syringe filters. Failure to remove suspended solids will result in erratic and inaccurate refractive index measurements.

How Refractometers Work

Physically a refractometer is composed of a light source, a prism, and a linear detector array. As illustrated in the next graphic, an illumination lens is used to direct the light from the light source to the prism, and a collection lens collects the light that is reflected from the prism-sample interface and directs it towards the linear detector array. In modern digital refractometers the light source is typical a semiconductor laser at about 589 nm (yellow light). The purpose of the illumination lens is to create a focusing beam or cone of light incident upon the prism-material interface that ranges in angles of incidence between qmin and qmax. The critical angle qc of the prism-sample interface must be such that qmin < qc < qmax, where qc is the angle q1 at which q2 becomes 90º. From Equation (2), in order for q2 = 90º, the argument of the arcsin on the right-hand side of the equation must equal unity. Using n2 = n for the index of refraction of the material under test and np = n1 for the index

of refraction of the prism, the critical angle can be expressed as Equation (3):

$$\theta_c = \arcsin\left(n_2 / n_1\right) = \arcsin\left(n / n_p\right)$$



A unique property of the critical angle is that for all angles larger than qc, 100% of the light is reflected from the interface and none transmits. For angles inside of the prism that are less than qc some light transmits into the sample material and therefore less than 100% of the light is reflected. In other words, for all rays in the beam of light focusing in the prism that are greater than the critical angle, 100% of the light is reflected off of the prism-material interface and propagates towards the collection lens and then on to the linear detector. The ray that is incident upon the prism-sample interface at qc will strike the linear detector at a point x = xc. By analyzing the detected light levels from x = 0 to x = xmax on the detector, the software of the refractometer detects the position xc since for xc < x < xmax, the light level is constant across the detector array (cannot get any more than 100% of the light reflected!). With a well-calibrated refractometer, the detector position xc is mapped back to a critical angle qc, which from Equation (3) and knowing the index of refraction of the prism np, the index of refraction n of the sample can be calculated and reported.

In addition to being wavelength sensitive, the index of refrac-

tion for any material changes slightly with temperature. For water at 20ºC (68ºF) the index of refraction is 1.333 and changes by -0.001 for every degree Centigrade. This may not seem like much, but for a 5ºC change in temperature of a coffee solution, the measured index of refraction will change by -0.0005 and the reported TDS value will change by 0.25% if thermal affects are not accounted for.

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