

Introduction

The RI-DS Program is an Excel® -based program for personal computers using the Windows operating system which allows generation of tables relating dry substance and refractive index for corn syrups, high fructose corn syrup and blends of these products with sucrose. In conjunction with the refractive index method included in this manual, the RI-DS Program may be used to determine the dry substance of corn syrups of known composition.

Development of Dry Substance Measurement for Corn Syrups

The measurement of dry substance (DS) of commodities containing water is an integral part of trade in a wide variety of common food and industrial products. In the trade of corn syrups, high fructose corn syrups and blends of these products with sucrose, accurate knowledge of dry substance is important for both commercial consideration and for proper use of the product by the customer. Since corn sweeteners are now a substantial portion of the sweeteners used in food around the world, simple, fast and accurate means of determining dry substance are vitally important to corn refiners and the food industry.

Traditionally, dry substance of both corn sweeteners and liquid sugars were measured by use of hydrometers. For corn sweeteners, DS was reported in degrees Baume', while sucrose hydrometer readings were reported in degrees Brix. Tables relating Baume' to dry substance were first published in 1943.

These tables served the industry well, until advances in technology rendered the Baume tables incomplete. The first advance was the enzymatic hydrolysis of starch in the 1950s. By allowing for the production of diverse compositions at the same DE, the original tables became invalid. From 1965-1975, the isomerization of D-glucose to D-fructose, and their separations by chromatography on an industrial scale, increased the variety of available saccharide compositions, further eroding the validity of the tables.

Prompted by these developments, the Corn Refiners Association, Inc. sponsored three updates to the dry substance tables. In 1976, the Association sponsored an update, based on refractive index, for glucose syrup and the first high fructose corn syrup (HFCS 42). The 1980 update, again based on refractive index, developed tables for all fructose syrups and their most common blends with sucrose and invert sugar syrups. Re-measuring and reconciling previous sample types and data in terms of density and specific gravity lead to the 1984 tables. This work has been fully described in the scientific literature listed in the reference section.

The laboratory operation of refractometers for the determination of dry substance in corn syrups is described in Standard Analytical Method REFRA..01 published by Corn Refiners Association, Inc. and reprinted in this manual.

Because corn syrups are composed of mixtures of saccharides with different physical properties, accurate knowledge of composition is essential to determine dry substance using the refractive index method. Users may use the RI-DS computer program to determine refractive index-dry substance relationships, as well as commercial Baume', specific gravity and weight per gallon of syrup either by selecting from a menu of typical product compositions offered by corn refiners, or by entering customized compositional data into the program.

Downloading the RI-DS Program

1. Hardware and Software Requirements. This program has been tested with Microsoft Windows operating systems through Windows 10, and Microsoft Excel through Microsoft 365 Version MSO 16.0 (09/2019).
2. Download the program from the Corn Refiners Association, Inc. website (www.corn.org) by clicking on the link “RI-DS Program” at: www.corn.org/policies/product-safety-quality
3. Clicking on the link will automatically download a Zip file (CRA_RI-DS-Version4.Zip) to your download folder.
4. Create a new folder where you will store the RI-DS program and files. Copy the Zip program to this directory and click to expand the files in the Zip program to the new directory. Four new files will be created:
CRA RI-DS Version4.XLS
CRA RI-DS Version4.XLT

CRA RI-DS Version4 (SI units).XLS
CRA RI-DS Version4 (SI units).XLT

The two program files (XLS) are identical except that the SI program files displays results in metric SI (Système international d'unités) units.

Both the XLS and XLT files for each program are necessary to run the RI-DS program successfully. Make sure that they remain in the same folder on your computer. They will automatically connect to one another, and do not require you to create an association.

Starting the RI-DS Program

1. Before starting the program, have ready the following information:

Designation of Syrup (trade name, DE description or other identification) Sulfated Ash content (Dry Basis)

Saccharide Composition (as % of total saccharide content) Fructose content (%)

Sucrose content (%)

Dextrose content (%)

Maltose (DP₂) content (%)

Maltotriose (DP₃) content

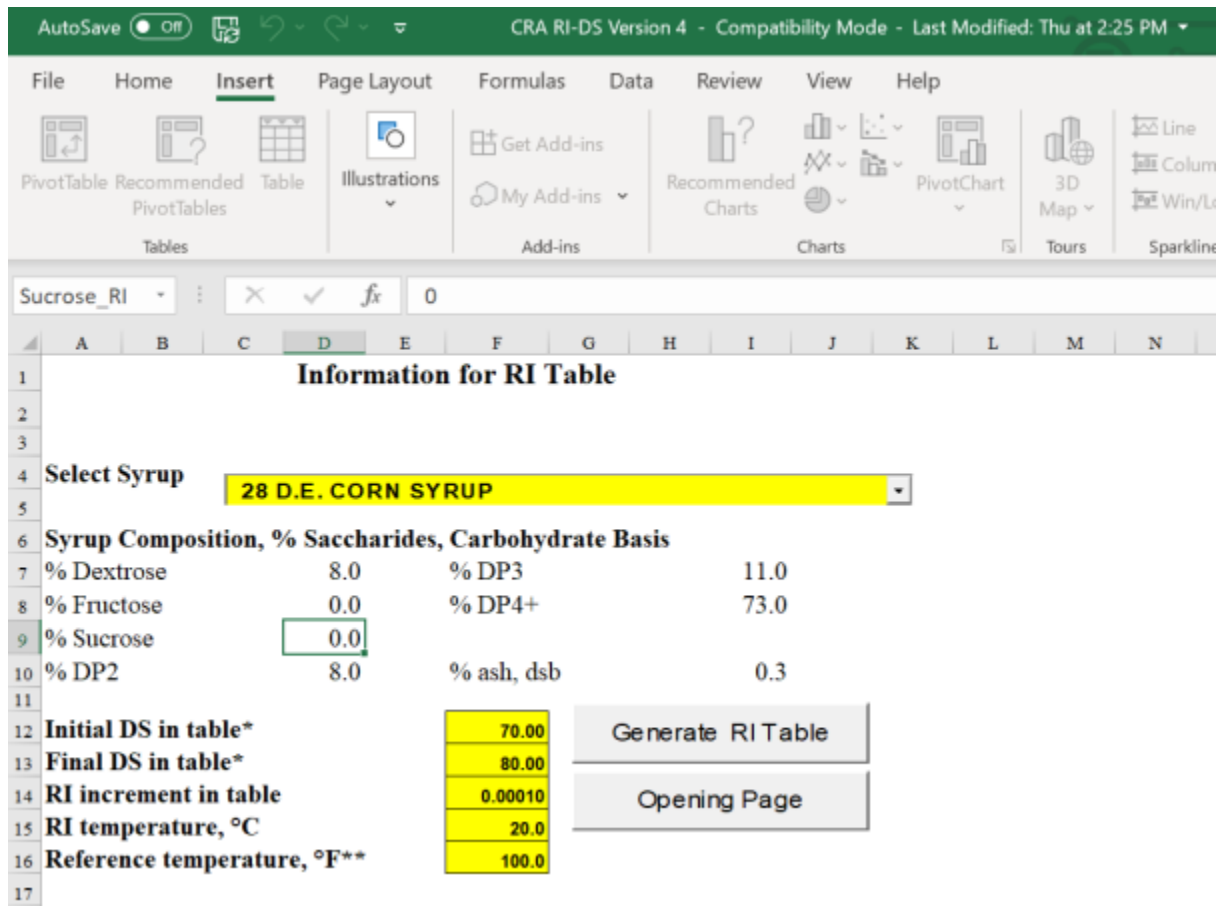
(%)

Higher Saccharides (DP₄₊) content (%)

2. To start the RI-DS Program, open Excel and double-click on the .XLS file. (The .XLS file does not need to be opened.) Depending on which version of Windows/Excel is being used you will be asked to permit the he program to run macro files. Upon opening the program, you may see the screen above. The RI-DS Program will not run unless you enable macros. After you enable macros you will be taken to the title page.
3. On the title page, you will be given the option to select one of the following: RI Table, DS Table, Brix Table, Individual Calculations or Syrup Definitions.
4. Select your choice by clicking on the corresponding button, and then turn to the section of this manual with that title for further information.

Refractive Index (RI) Table

1. To use the RI Table function, click on the corresponding button on the title page of the program. This will bring you to the RI Tables sub-menu, which looks like this:



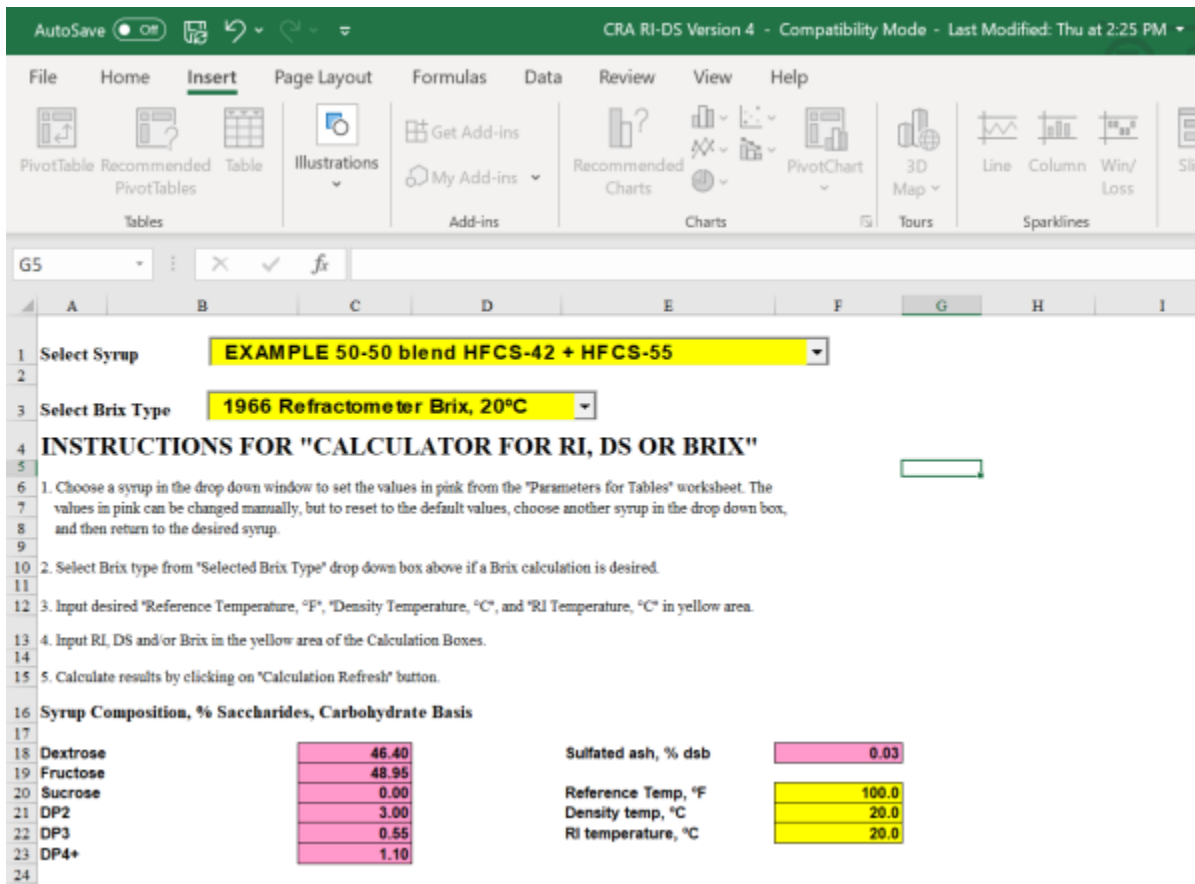
2. From this menu, you can generate RI tables of standard compositions of corn syrup, or return to the home page, by clicking the **Opening Page** tab at the bottom of the screen. To create a RI table click on the arrow of the **Select Syrup** drop down menu. To create a RI table with the default characteristics listed in the yellow boxes, press the **Generate RI Table** button. You will see the program working, indicated by the activity in the calculation bar. After a few seconds, a table will generate. This table will have the syrup type and characteristics labeled at the top of the page. The number of tables you generate per session will determine the name of each table you generate. For example, if this is your first RI table, the program will name this CRA RI-DS Version 21.xls. Subsequent versions will be saved as CRA RI-DS Version 22.xls, CRA RI-DS Version 23.xls etc.
3. At this point, you can either print the table, save the table, or return to the opening page. To print the table, you can either click on the printer icon in the tool bar, or click on **File**,

then

Print from the drop-down menu. The **Opening Page** button will not print on the table.

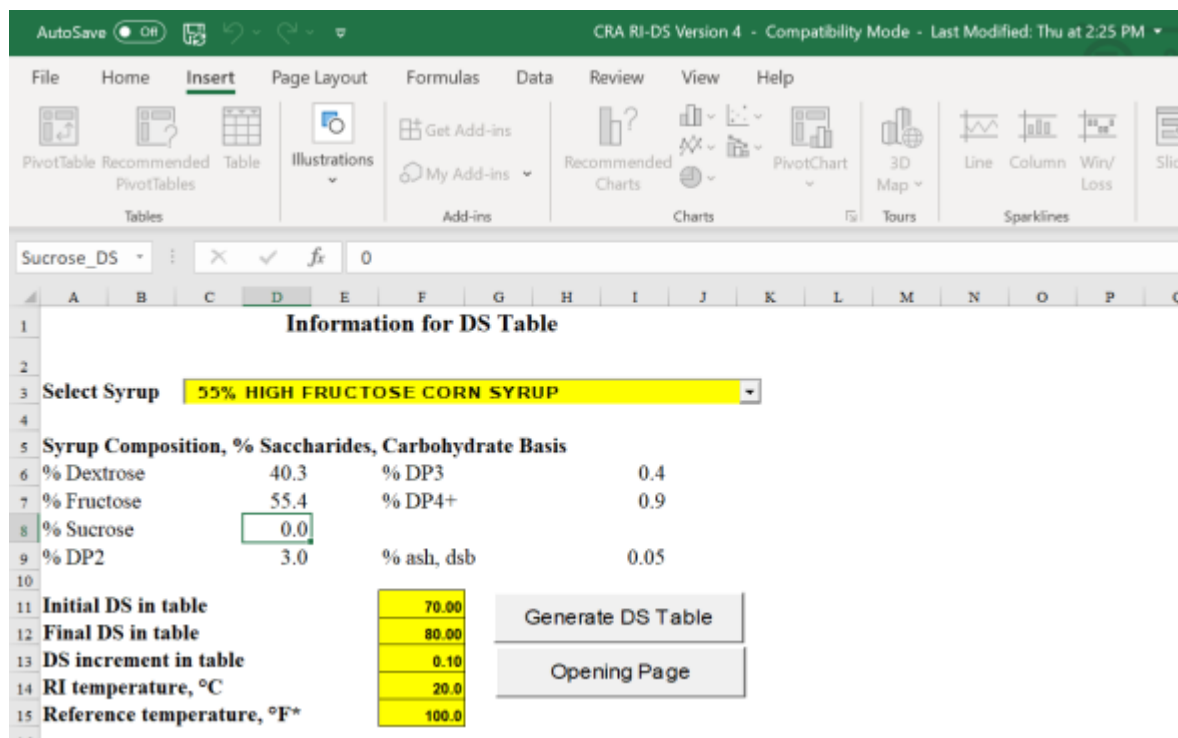
4. To save these files, click on the diskette icon in the toolbar, or click on **File**, then select **Save** to save with the current name and directory, or **Save As** to change the file name or target directory.
5. To return to the opening page, simply press the **Opening Page** button.

6. You can also create custom tables, you may change any of the following parameters in the yellow boxes: **Starting DS in Table, Final DS in Table, RI Increment in Table, RI Temperature, C and/or Reference Temperature, F**. This is done by selecting the yellow cell beside the parameter of your choice and re-typing the information you wish the table to reflect.
7. Additionally, you can create RI Tables for custom blends of syrups, by first creating a new syrup definition in the **Syrup Definition** section of the program (see this section of the manual for further details). Once created, you can select this from the **Select Syrup** drop down menu and proceed as normal **DS Tables**.



Dry Substance (DS) Tables

1. To use the DS Table function, click on the corresponding button on the title page of the program. This will bring you to the DS Tables sub-menu, which looks like this:



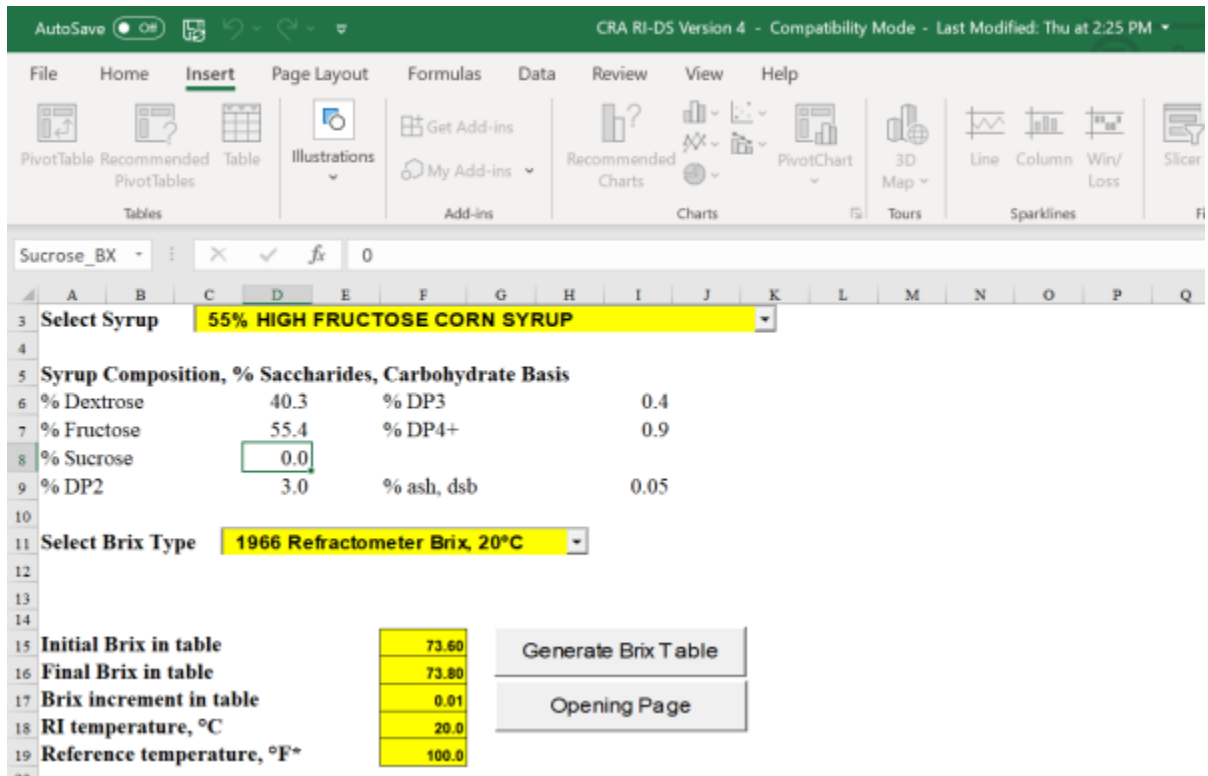
2. From this menu, you can generate DS tables of standard compositions of corn syrup, or return to the home page, by clicking the **Opening Page** tab at the bottom of the screen. To create a DS table, click on the arrow of the **Select Syrup** drop down menu. To create a DS table with the default characteristics listed in the yellow boxes, press the **Generate DS Table** button. You will see the program working, indicated by the activity in the calculation bar. After a few seconds, a table will generate. This table will have the syrup type and characteristics labeled at the top of the page. The number of tables you generate per session will determine the name of each table you generate. For example, if this is your first DS table, the program will name this CRA RI-DS Version 21.xls. Consequent versions will be saved as CRA RI-DS Version 22.xls, CRA RI-DS Version 23.xls etc.
3. At this point, you can either print the table, save the table, or return to the opening page. To print the table, you can either click on the printer icon in the tool bar, or click on **File**, then **Print** from the drop-down menu. The **Opening Page** button will not print on the table.
4. To save these files, click on the diskette icon in the toolbar, or click on **File**, then select **Save** to save with the current name and directory, or **Save As** to change the file name or target directory.

5. To return to the opening page, simply press the **Opening Page** button.
6. You can also create custom tables by changing any of the following parameters in the yellow boxes: **Initial DS in Table; Final DS in Table; DS Increment in Table; RI Temperature, C; and/or Reference Temperature, F**. This is done by selecting the yellow cell beside the parameter of your choice and entering the information you wish the program to calculate.
7. You may also create DS Tables for custom blends of syrups by first creating a new syrup definition in the **Syrup Definition** section of the program (see this section of the manual for further details). Once created, you can select this from the Select Syrup drop down menu and proceed as normal.

Brix Table

1. To use the Brix Table function, click on the corresponding button on the title page of the program.

This will bring you to the Brix Table sub-menu, which looks like this:



2. From this menu, you can generate Brix tables of standard compositions of corn syrup, or return to the home page, by clicking the **Opening Page** tab at the bottom of the screen. To create a Brix table, click on the arrow of the **Select Syrup** drop down menu. In this sub-menu, you will also need to select the Brix type, by clicking on the arrow of the **Select Brix Type** drop down menu. Your choices are: 1936 Refractometer Brix, C; 1966 Refractometer Brix, C; or Hydrometer Brix, C.

3. To create a Brix table with the default characteristics listed in the yellow boxes, press the **Generate Brix Table** button. You will see the program working, indicated by the activity in the calculation bar. After a few seconds, a table will generate. This table will have the syrup type and characteristics labeled at the top of the page. The number of tables you generate per session will determine the name of each table you generate. For example, if this is your first Brix table, the program

will name this CRA RI-DS Version 21.xls. Subsequent versions will be saved as CRA RI-DS Version 22.xls, CRA RI-DS Version 23.xls etc.

4. At this point, you can either print the table, save the table, or return to the opening page. To print the table, you can either click on the printer icon in the tool bar, or click on **File**, then **Print** from the drop-down menu. The **Opening Page** button will not print on the table.
5. To save these files, click on the diskette icon in the toolbar, or click on **File**, then select **Save** to save with the current name and directory, or **Save As** to change the file name or target directory.
6. To return to the opening page, simply press the **Opening Page** button.
7. You can also create custom tables by changing any of the following parameters in the yellow boxes: **Initial Brix in Table; Final Brix in Table; Brix Increment in Table; RI Temperature, C; and/ or Reference Temperature, F**. This is done by selecting the yellow cell beside the parameter of your choice and entering the information you wish the program to calculate.
8. Additionally, you can create Brix tables for custom blends of syrups, by first creating a new syrup definition in the **Syrup Definition** section of the program (see this section of the manual for further details). Once created, you can select this from the **Select Syrup** drop down menu and proceed to generate the desired tables

different parameter cells, remember to hit **Enter** to confirm your selection. Each time you change parameters, the **Calculation Re- fresh** button will turn red, indicating that you must click it to generate new calculations. This information can be reflected as: **Calculation Using RI, Calculation using DS** or whichever Brix type you select from the Brix Type drop down menu.

5. When changing parameters in the pink box, remember that the saccharide concentration must equal 100%. If you enter values that cause the concentration to equal more or less than 100%, you will receive an error message telling you that you must change your other parameters to compensate. If this message does not show up automatically, it will show up when you try to refresh the calculations.
6. After generating the syrup composition and/or changing parameters, you can also generate calculations by changing the **RI at 20 C, %DS** or **Brix (DS of 100% Sucrose)** by changing these parameters in the yellow cells of the corresponding boxes. Again, you will need to refresh the calculations when you finish entering your parameters.
7. Additionally, you can create individual calculations for custom blends of syrups, by first creating a new syrup definition in the Syrup Definition section of the program (see this section of the manual for further details). Once created, you can select this from the Select Syrup drop down menu and proceed as normal.

REFRACTIVE INDEX - continued

2. If the refractometer temperature is lower than room temperature, there is a tendency for the prism to fog, especially at high relative humidities. Also, thick viscous syrups present difficulties which are best overcome at higher temperatures where their viscosities are sharply decreased.

Hose connections between the water bath and refractometer must be the shortest length possible to avoid temperature differences. Hose insulation is recommended. A 1° C temperature discrepancy corresponds to a dry substance discrepancy of about 0.1%.

3. For accurate measurements, particularly with warm samples, speed in application of the sample and closing the prism is imperative. No more than 2-3 seconds should be consumed in this operation. Also, water used to rinse the prism faces should be at the measuring temperature specified.
4. When analyzing freshly prepared solutions of crystalline sugars, mutarefractation equilibrium must be attained before accurate refractive index values can be obtained. Equilibration can be hastened by heating and is obtained with the optical rotation stabilizes. In addition, solutions of pure sugars, and syrups exhibiting a crystallization tendency, must be completely free of all crystalline materials because they prohibit accurate refractive index measurement.
5. The refractive index/dry substance relationship will vary with composition. A computer program, RI-DS, which will produce tables based upon user-supplied saccharide compositions, is available on the Corn Refiners Association, Inc. website (see Calculations). Tables suited for the needs of particular end-users of these products may be produced, e.g., tables contained in Quality Guidelines and Analytical Procedures Bibliography for "Bottlers" High Fructose Corn Syrup 42 and 55, International Society of Beverage Technologists (www.bevtech.org). For discussion of the mathematical models necessary for construction of tables for products of different composition, see J. Chem. Eng. Data, No. 1, January 1979, pp. 44-45, J. Chem Eng. Data, Vol. 25, No. 3, July 1980, pp. 277-282 and J. Agr. Food Chem., Vol. 32, 1984, pp. 974-979.

REFRACTIVE INDEX - continued

METHOD HISTORY

Corn Syrup, Refractive Index (E-54), Date of Acceptance 5-07-1956,
Revised 10-9-2009.

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Acknowledgments

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Thomas Gagnon, formerly of Tate & Lyle Americas, was instrumental in the creation of the Windows-based Microsoft Excel ®-based program. CRA would also like to extend a special thanks to Jerry Geske, formerly of Tate and Lyle Americas, for his assistance with the program's development and data reconciliation.

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