Guide to the Corn Refiners Association, Inc. RI-DS Program

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INTRODUCTION

The RI-DS Program is an Excel-based program for IBM compatible personal computers 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 the predominant sweetener in the United States, 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 E-54 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. Tables of refractive index-dry substance relationships for the most typical product compositions currently offered by member companies of Corn Refiners Association, Inc. are included in this manual. 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 by entering compositional data into the program.

Downloading the RI-DS Program

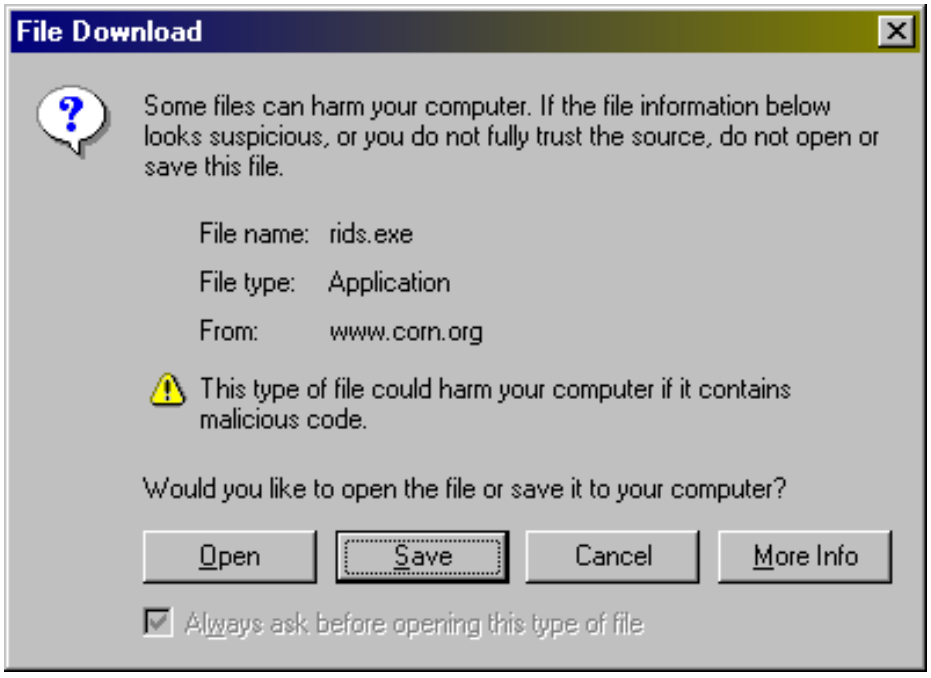
1. Hardware and Software Requirements. This program has been tested with Windows 95, 98, 98SE, XP, ME, 2000 and NT operating systems using Microsoft Office Suites 95, 97, 2000 or XP. The system requirements are set by the operating system and the office suite requirements.

2. Download the program from the Corn Refiners Association, Inc. website (www.corn.org) by clicking on the link "RI-DS Program Self-Extracting Zip File".

3. You will be prompted to indicate where you want to save the file entitled "rids.exe", with a screen similar to the one below. If you wish to save the program to a diskette, insert a diskette into the a:\ drive of your computer. Click the "Save" button, and you will be prompted to indicate where to save the program, which will download the files to your computer or disk. You will then be prompted to select "Open", "Open Folder" or "Close". By clicking "Open", you will initiate the auto extraction of the program in the file you indicated. By clicking "Open Folder", you can go to the folder you saved the file in, and auto extract the program by double clicking the icon of the .exe file.

4. You can also download the program by clicking the "Open" button, which will automatically extract the program, then ask you to indicate where you would like the information saved. Click the "Browse" button to select where you would like to save the file. Click the "Unzip" button to complete the download.

Note: Both of the files contained in the rids.exe file 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

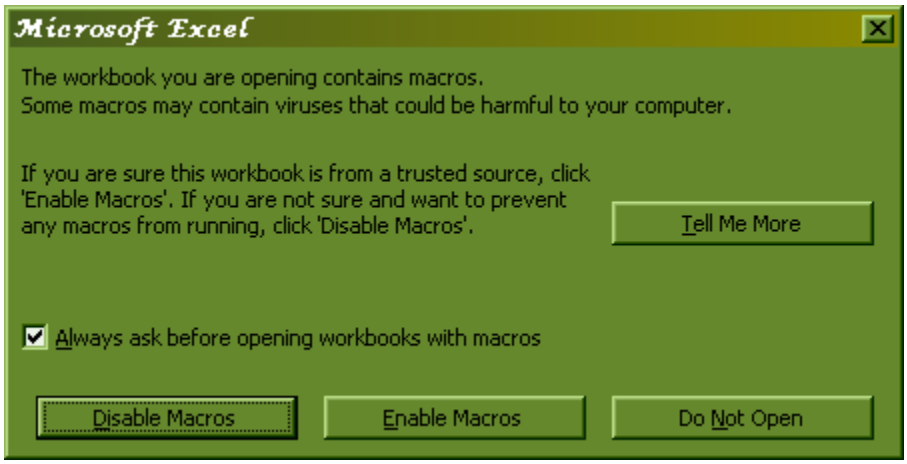
1. Before starting the program, have ready the following information:

   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 (DP_2) content (%)
   Maltotriose (DP_3) content (%)
   Higher Saccharides (DP_4+) content (%)



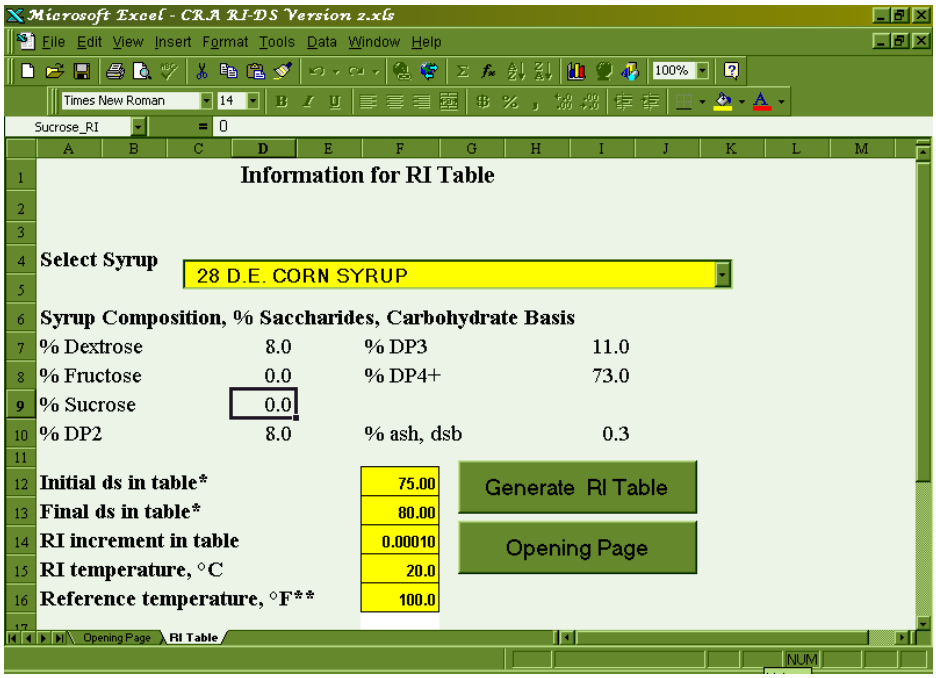
2. To start the RI-DS Program, open Excel and double-click on the .xls file. (The .xlt file does not need to be opened.) Upon opening the program, you may see the screen above. If you wish to use the RI-DS Program, you should read this screen and determine whether or not you wish to proceed and "enable macros." The RI-DS Program will not run unless you chose to "enable macros." If you chose to "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.

RI Table

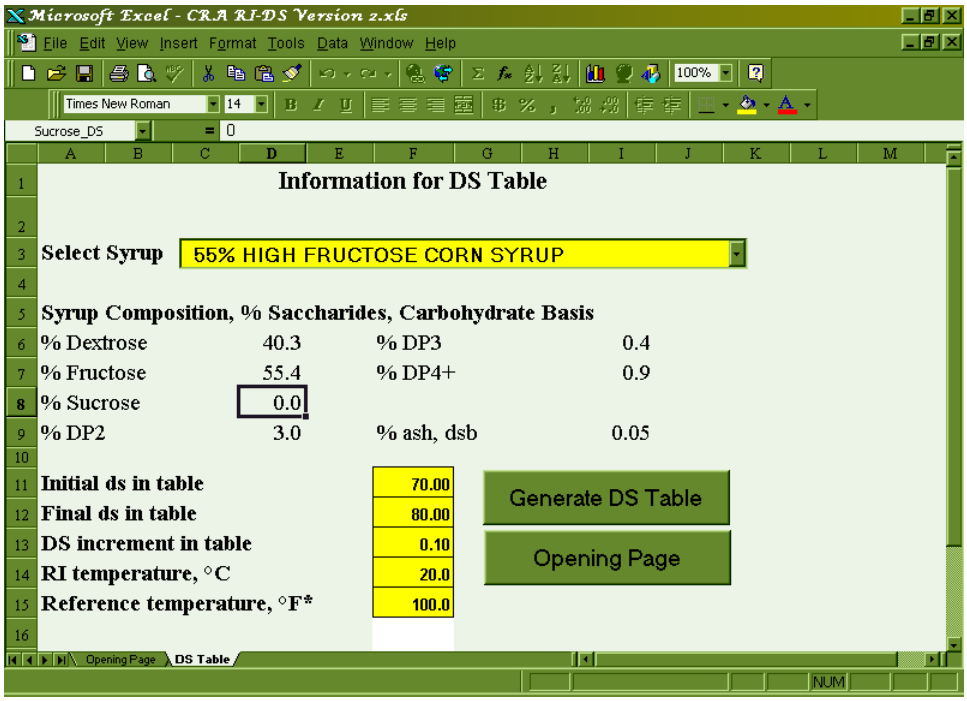
1. To use the RI Table function, click on the corresponding button on the title page of the program. This will bring you to the RI Tables sub-menu, which looks like this:



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.** 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. **Note:** 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** 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**

1.

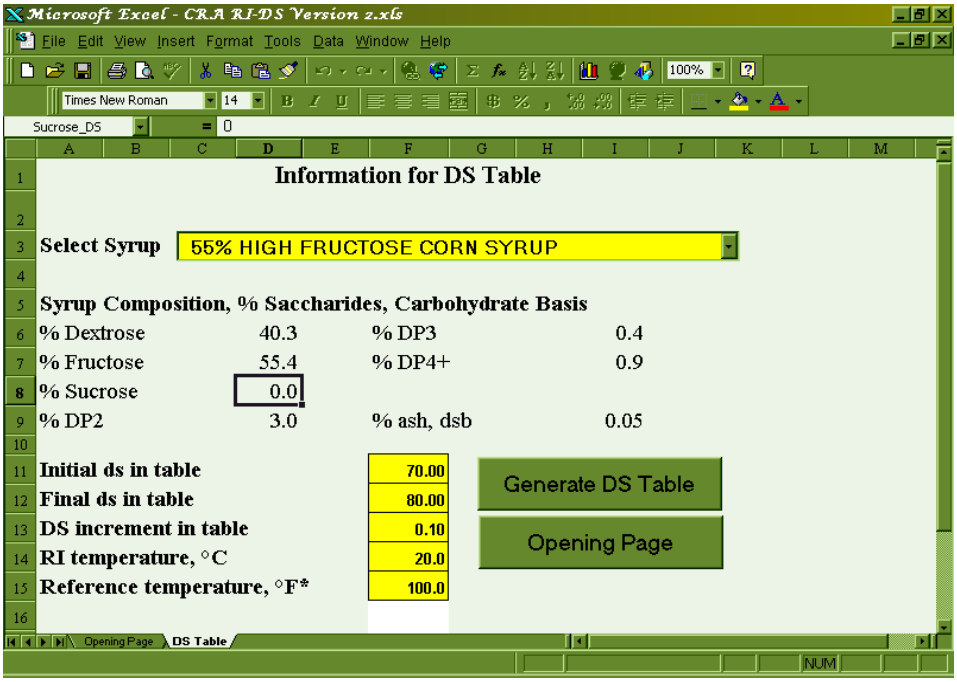


To use the RI Table function, click on the corresponding button on the title page of the program. This will bring you to the RI Tables sub-menu, which looks like this:

2. From this menu, you can generate 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.

DS Tables

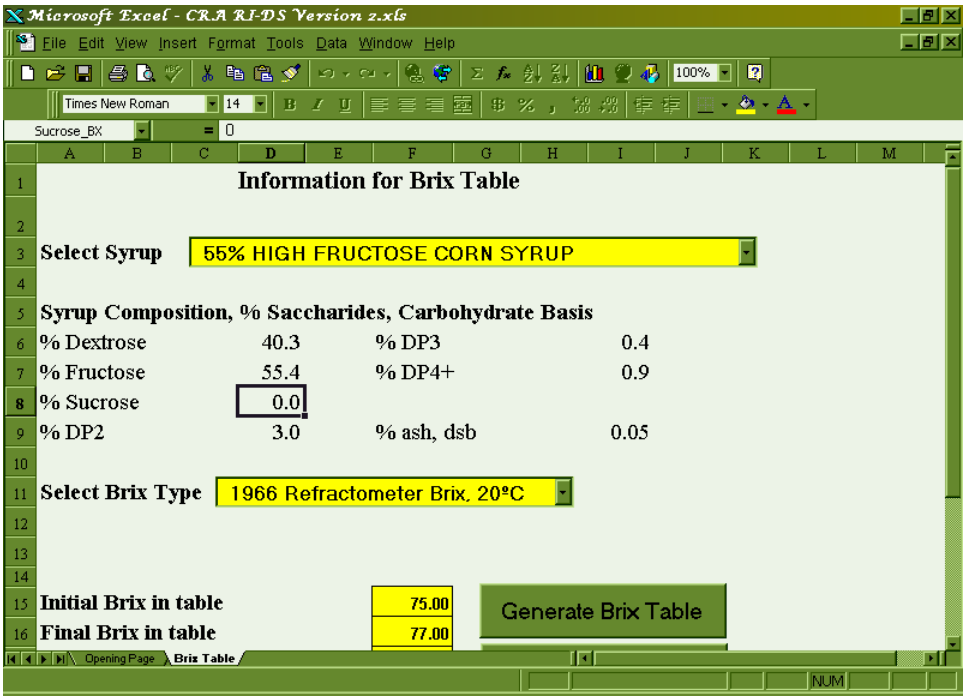
1. To use the RI Table function, click on the corresponding button on the title page of the program. This will bring you to the RI Tables sub-menu, which looks like this:



2. From this menu, you can generate 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. **Note:** 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. Additionally, you can 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:

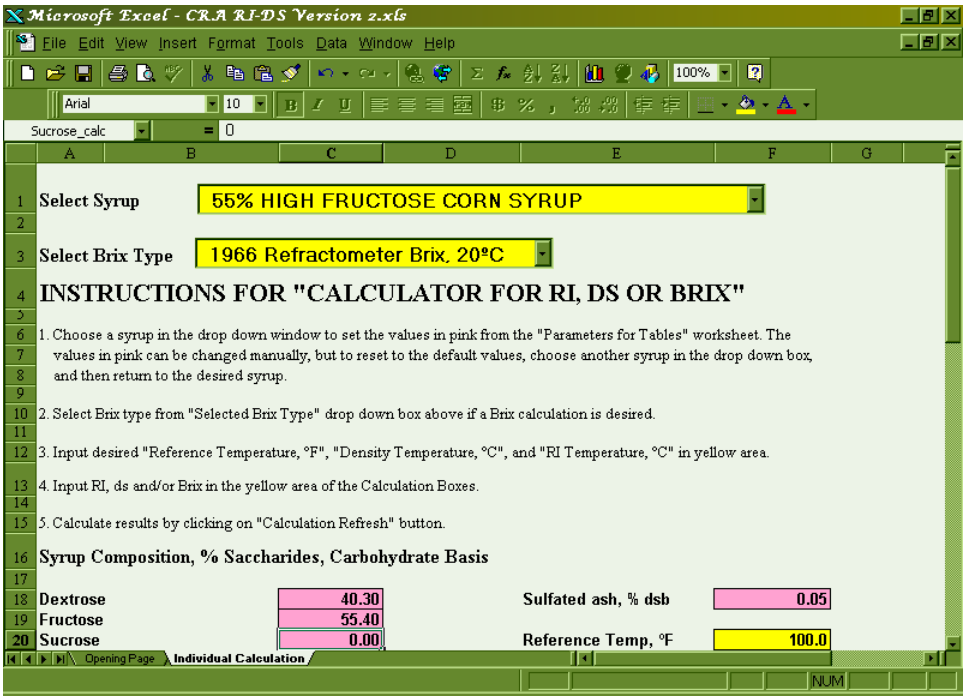


2. From this menu, you can generate Brix tables of standard compositions of corn syrup, or return to the home page, by clicking the **Opening Page** tab at the bottom of the screen. To create a Brix table, click on the arrow of the **Select Syrup** drop down menu. In this sub-menu, you will also need 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 table 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.** Consequent 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. **Note:** 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** 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

Individual Calculations

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



2. From this menu, you can generate individual calculations for standard compositions of corn syrup, or return to the home page, by clicking the **Opening Page** tab at the bottom of the screen.

3. Select a syrup type by clicking on the arrow of the **Select Syrup** drop down menu.

4. In this sub-menu, you can also select the Brix type, by clicking on the arrow of the **Select Brix Type** drop down menu, as well as change a number of different parameters, indicated by the pink and yellow cells. When entering numbers into the different parameter cells, remember to hit **Enter** to confirm your selection. Each time you change parameters, the **Calculation Refresh** 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.

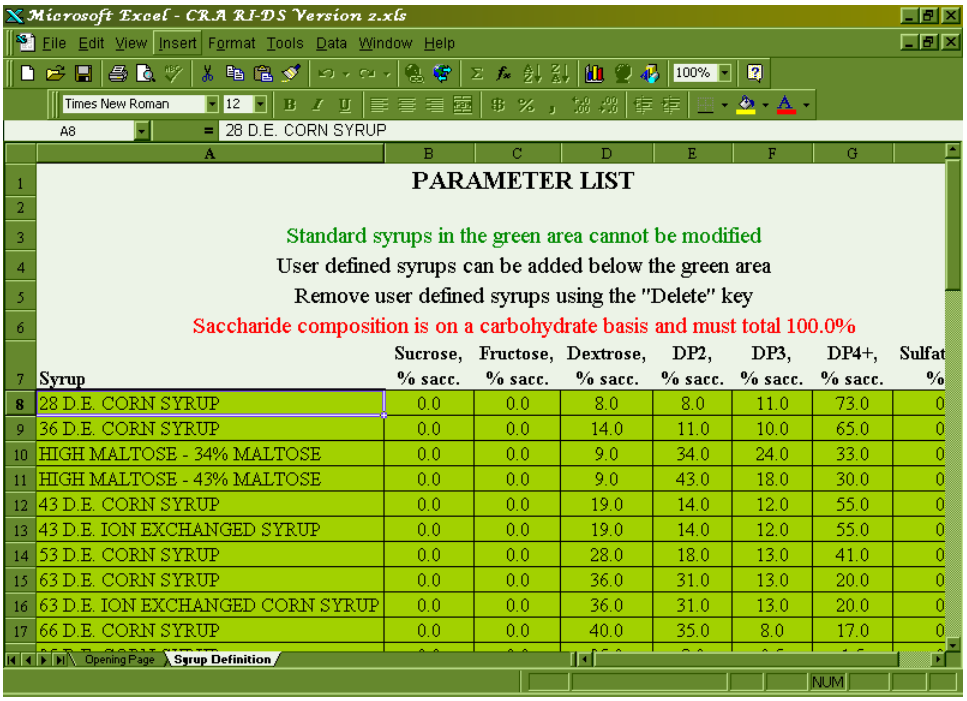
5. When changing parameters in the pink box, remember that the saccharide concentration must equal 100%. If you enter in a value that causes the concentration to equal more or less than 100%, you will receive an error message telling you that you must change your other parameters to compensate. If this 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.

Syrup Definition

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



Syrup	Sucrose, % sacc.	Fructose, % sacc.	Dextrose, % sacc.	DP2, % sacc.	DP3, % sacc.	DP4+, % sacc.	Sulfat %
28 D.E. CORN SYRUP	0.0	0.0	8.0	8.0	11.0	73.0	0
36 D.E. CORN SYRUP	0.0	0.0	14.0	11.0	10.0	65.0	0
HIGH MALTOSE - 34% MALTOSE	0.0	0.0	9.0	34.0	24.0	33.0	0
HIGH MALTOSE - 43% MALTOSE	0.0	0.0	9.0	43.0	18.0	30.0	0
43 D.E. CORN SYRUP	0.0	0.0	19.0	14.0	12.0	55.0	0
43 D.E. ION EXCHANGED SYRUP	0.0	0.0	19.0	14.0	12.0	55.0	0
53 D.E. CORN SYRUP	0.0	0.0	28.0	18.0	13.0	41.0	0
63 D.E. CORN SYRUP	0.0	0.0	36.0	31.0	13.0	20.0	0
63 D.E. ION EXCHANGED CORN SYRUP	0.0	0.0	36.0	31.0	13.0	20.0	0
66 D.E. CORN SYRUP	0.0	0.0	40.0	35.0	8.0	17.0	0

2. The Parameter List is equipped with 13 standard syrup compositions, indicated in the green cells, that cannot be modified. Directly following these standard compositions are several yellow cells that can be utilized to create user-defined syrups. To do this, scroll down to the yellow area and enter in a name for the syrup. Go across the table, and enter in the composition of the syrup. **Note:** Saccharide composition is on a carbohydrate basis and must total 100.0%. The program will not allow for the creation of a syrup above or below that value and will give an error message, indicating that you must change your values to create the proper balance.
3. Once created, a user-defined syrup can be utilized in other parts of the program. These will be located in the **Select Syrup** drop down menu in all other parts of the program. Should you wish to delete a user-defined syrup, highlight the name and composition cells for that syrup to select the information in that row. Hit the **delete** button to erase the data. **Note**: The program will not allow you to select the entire row and delete, as there is formatting that is write-protected.
4. In the event that you run out of available space in the yellow area, select the bottom row, then click **Insert** on the toolbar. Select **Row** from the drop down menu. Repeat as needed.

REFRACTIVE INDEX

PRINCIPLE

The index of refraction of a substance is the ratio of the velocity of light in a vacuum to its velocity in the substance. This, in turn, is dependent on composition, concentration (e.g. dry substance) and temperature of the substance. When solids composition and temperature are known, index of refraction is a measure of dry substance (Note 1).

SCOPE

The method is applicable to corn syrup (including those contain-ing high fructose), maltodextrin solutions, dextrose and sucrose solutions, invert sugar, and blends.

SPECIAL APPARATUS

1. Refractometer: An instrument is necessary with a range of indices from 1.32 or lower to 1.53 or higher, accurate to 0.0001 unit. It should be so constructed that samples can be introduced with ease and speed, and the instrument should be easily cleaned.

   Follow the manufacturer's instructions for use of the particular instrument. Standardize using purified water and the test block supplied with the instrument; calibration with the test block must be performed at the temperature specified by the supplier. The refractometer is convenient-ly standardized using sucrose solutions of known concentration and refractive index (Note 2).

2. Water Bath: Operate at a temperature of 20 C or 45 C. It should be sufficient in size to allow circulation of water, by means of a pump, through the refractometer so that the refractometer temperature, especially the prism faces, is controlled within ± 0.2 C of that prescribed for the bath (Note 3).

3. Light Source: Frosted incandescent bulb

PROCEDURE

Dilute syrups are best applied with a dropper, while concentrated syrups are handled most conveniently with a fire-polished glass rod. After water bath and refractometer have reached the prescribed temperature, apply sample to the prism face, and close the prism in minimum time possible, so as to avoid sample concen-tration change (Note 4). Examine the optical field through refractometer observation lens; if the light and dark fields are not separated by a sharp line, remove the sample, clean and dry the prism faces, and apply a fresh sample. Read the index, estimating to the nearest 0.0001 unit, as soon as temperature equilibrium is indicated by constant

readings (not more than 3 minutes) (Note 5). Prior to applying any sample, rinse the prism faces with purified water at the bath temperature (20 C or 45 C), to facilitate temperature equilibration.

CALCULATION

If desired, obtain the percent dry substance of the sample by reference to the appropriate attached table (Note 6).

NOTES AND PRECAUTIONS

1. The attached tables relating refractive index to dry sub-stance for commercial corn syrups, high fructose corn syrups and selected blends were developed based on investigations by Augustana Research Foundation (Rock Island, Illinois), with the financial support of the Corn Refiners Association, Inc. See: Anna M. Wartman, Caroline Hagberg and Morton A. Eliason, Journal of Chemical and Engineering Data, Vol. 21, No. 4, October 1976, pages 459-468; Anna M. Wartman, Alan J. Bridges, and Morton A. Eliason, Journal of Chemical and Engineering Data, Vol. 25, No. 3, July 1980, pages 277-282. See also: Frank A. Kurtz and Morton A. Eliason, Journal of Chemical and Engineering Data, Vol. 24, No. 1, January 1979, pages 44-45. Tables relating refractive index and concentration for pure dextrose solutions have been reported by F. W. Zerban and M. Martin, Journal of the Association of Official Agricultural Chemists, Vol. 27, 1944, page 295. Similar data for solutions of pure fructose, pure maltose and pure sucrose are given in the following articles: U. S. Department of Commerce, National Bureau of Standards, Circular No. C440, Table 129; R. C. Weast, Handbook of Chemistry and Physics, 53rd Edition, Chemical Rubber Company, Cleveland, Ohio, 1972, page D-196; and International Sugar Journal, Vol. 39, 1937, page 225.
2. Sucrose solutions of known concentration are easily prepared using purified crystalline sucrose from the National Bureau of Standards. These solutions, when examined using the techniques described under “Procedure,” are excellent for refractometer standardization. Refractive indices for sucrose solutions at the concentrations and temperatures given below, are reported by the National Bureau of Standards.

SOLIDS,%	REFRACTIVE INDEX AT DEGREES C					
	20.0	30.0	35.0	40.0	45.0	50.0
45.0	1.4099	1.4082	1.4073	1.4064	1.4054	1.4044
46.0	1.4119	1.4102	1.4093	1.4084	1.4074	1.4064
47.0	1.4139	1.4122	1.4114	1.4104	1.4095	1.4084
48.0	1.4160	1.4143	1.4134	1.4125	1.4115	1.4105
49.0	1.4180	1.4164	1.4155	1.4145	1.4135	1.4125
50.0	1.4201	1.4184	1.4175	1.4166	1.4156	1.4146
51.0	1.4222	1.4205	1.4196	1.4187	1.4177	1.4167
52.0	1.4244	1.4226	1.4217	1.4208	1.4198	1.4188
53.0	1.4265	1.4248	1.4238	1.4229	1.4219	1.4209
54.0	1.4286	1.4269	1.4260	1.4250	1.4240	1.4230
55.0	1.4308	1.4291	1.4281	1.4272	1.4262	1.4252
56.0	1.4330	1.4312	1.4303	1.4293	1.4283	1.4273
57.0	1.4352	1.4334	1.4325	1.4315	1.4305	1.4295
58.0	1.4374	1.4356	1.4347	1.4337	1.4327	1.4317
59.0	1.4396	1.4379	1.4369	1.4359	1.4349	1.4339
60.0	1.4419	1.4401	1.4391	1.4382	1.4372	1.4361
61.0	1.4442	1.4424	1.4414	1.4404	1.4394	1.4384
62.0	1.4464	1.4446	1.4437	1.4427	1.4417	1.4406
63.0	1.4488	1.4469	1.4460	1.4450	1.4440	1.4429
64.0	1.4511	1.4492	1.4483	1.4473	1.4463	1.4452
65.0	1.4534	1.4516	1.4506	1.4496	1.4486	1.4475

3. If the refractometer temperature is lower than room temperature, there is a tendency for the prisms 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%.

4. 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.

5. When analyzing freshly-prepared solutions of crystalline sugars, mutarefraction equilibrium must be attained before accurate refractive index values can be obtained. Equili-bration can be hastened by heating and is obtained when 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.

6. Tables I and II contain dry substance-refractive index data at 20 C and 45 C for commercial corn syrups; similar data for high fructose corn syrups and several examples of blended products are contained in Tables III and IV. Table V contains ash and D.E. corrections for syrups having compositions slightly different from those represented in Tables I - IV.

   The refractive index/dry substance relationship will vary with composition. These tables are based upon the saccharide composition of typical corn syrups, high fructose corn syrups and blends at the time of publication. A computer program, RI-DS, which will produce tables based upon user-supplied saccharide compositions is available for purchase from Corn Refiners Association, Inc. 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, Society of Soft Drink Technologists, 4419 41st Street, Brentwood, MD 20722. 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.

   Abbreviations used in Tables I - V are identified as follows:

D.E.	= Dextrose Equivalent
D.S.	= Dry Substance
HM	= High Maltose
IX	= Ion-exchanged
D.B.	= Dry Basis
CS	= Corn Syrup
HFCS-42	= High Fructose Corn Syrup containing 42% (db) Fructose
HFCS-55	= High Fructose Corn Syrup containing 55% (db) Fructose
HFCS-90	= High Fructose Corn Syrup containing 90% (db) Fructose

Refractive Index — continued

Table 1 - Refractive Index - Commercial Corn Syrups - 20 C

D.E.	28	36	34HM	43HM	43	43IX
% Ash	0.3	0.3	0.3	0.3	0.3	0.03
D.B.						
DS						
0.0	1.3330	1.3330	1.3330	1.3330	1.3330	1.3330
2.0	1.3360	1.3360	1.3360	1.3360	1.3360	1.3360
4.0	1.3391	1.3390	1.3390	1.3390	1.3390	1.3390
6.0	1.3422	1.3421	1.3421	1.3420	1.3420	1.3420
8.0	1.3453	1.3452	1.3452	1.3452	1.3452	1.3452
10.0	1.3485	1.3484	1.3484	1.3483	1.3483	1.3483
12.0	1.3518	1.3517	1.3516	1.3515	1.3516	1.3515
14.0	1.3551	1.3549	1.3549	1.3548	1.3548	1.3548
16.0	1.3585	1.3583	1.3582	1.3581	1.3581	1.3581
18.0	1.3619	1.3617	1.3616	1.3615	1.3615	1.3615
20.0	1.3654	1.3651	1.3650	1.3649	1.3649	1.3649
22.0	1.3689	1.3686	1.3685	1.3684	1.3684	1.3684
24.0	1.3725	1.3722	1.3720	1.3719	1.3720	1.3720
26.0	1.3762	1.3758	1.3756	1.3755	1.3756	1.3756
28.0	1.3759	1.3795	1.3793	1.3791	1.3792	1.3792
30.0	1.3837	1.3832	1.3830	1.3828	1.3829	1.3829
32.0	1.3875	1.3870	1.3868	1.3866	1.3867	1.3867
34.0	1.3914	1.3909	1.3906	1.3904	1.3905	1.3905
36.0	1.3953	1.3948	1.3945	1.3943	1.3944	1.3944
38.0	1.3993	1.3988	1.3985	1.3982	1.3983	1.3983
40.0	1.4034	1.4028	1.4025	1.4022	1.4024	1.4023
42.0	1.4076	1.4069	1.4066	1.4063	1.4064	1.4064
44.0	1.4118	1.4111	1.4107	1.4104	1.4106	1.4105
46.0	1.4160	1.4153	1.4149	1.4146	1.4148	1.4147
48.0	1.4204	1.4196	1.4192	1.4188	1.4190	1.4190
50.0	1.4248	1.4240	1.4235	1.4231	1.4233	1.4233
52.0	1.4293	1.4284	1.4279	1.4275	1.4277	1.4277
54.0	1.4338	1.4329	1.4324	1.4320	1.4322	1.4322
56.0	1.4384	1.4375	1.4369	1.4365	1.4367	1.4367
58.0	1.4431	1.4421	1.4415	1.4411	1.4413	1.4413
60.0	1.4479	1.4468	1.4462	1.4457	1.4460	1.4460
62.0	1.4527	1.4516	1.4509	1.4504	1.4507	1.4507
64.0	1.4577	1.4565	1.4558	1.4552	1.4556	1.4555
66.0	1.4626	1.4614	1.4607	1.4601	1.4604	1.4604
68.0	1.4677	1.4664	1.4656	1.4651	1.4654	1.4654
70.0	1.4729	1.4715	1.4707	1.4701	1.4704	1.4704
72.0	1.4781	1.4767	1.4758	1.4752	1.4756	1.4755
74.0	1.4834	1.4819	1.4810	1.4803	1.4808	1.4807
76.0	1.4888	1.4873	1.4863	1.4856	1.486	1.486
78.0	1.4943	1.4927	1.4917	1.4909	1.4914	1.4913
80.0	1.4999	1.4982	1.4971	1.4964	1.4969	1.4968
82.0	1.5055	1.5038	1.5027	1.5019	1.5024	1.5023
84.0	1.5113	1.5094	1.5083	1.5075	1.5080	1.5079

Refractive Index continued

Table 1 - Refractive Index - Commercial Corn Syrups - 20 C

D.E.	53	63	63 IX	66	95	95 IX
% Ash D.B.	0.3	0.3	0.3	0.3	0.3	0.03
DS						
0.0	1.3330	1.3330	1.3330	1.3330	1.3330	1.3330
2.0	1.3359	1.3359	1.3359	1.3359	1.3359	1.3359
4.0	1.3389	1.3389	1.3389	1.3389	1.3388	1.3388
6.0	1.3420	1.3419	1.3419	1.3419	1.3417	1.3417
8.0	1.3451	1.3450	1.3450	1.3450	1.3447	1.3447
10.0	1.3482	1.3481	1.3481	1.3481	1.3478	1.3478
12.0	1.3514	1.3513	1.3513	1.3513	1.3508	1.3508
14.0	1.3546	1.3545	1.3545	1.3545	1.3540	1.3540
16.0	1.3579	1.3578	1.3578	1.3577	1.3572	1.3571
18.0	1.3613	1.3611	1.3611	1.3610	1.3604	1.3604
20.0	1.3647	1.3644	1.3644	1.3644	1.3636	1.3636
22.0	1.3681	1.3679	1.3679	1.3678	1.3669	1.3669
24.0	1.3716	1.3713	1.3713	1.3713	1.3703	1.3703
26.0	1.3752	1.3749	1.3749	1.3748	1.3737	1.3737
28.0	1.3788	1.3784	1.3784	1.3783	1.3772	1.3772
30.0	1.3825	1.3821	1.3821	1.3820	1.3807	1.3807
32.0	1.3862	1.3858	1.3858	1.3856	1.3842	1.3842
34.0	1.3900	1.3895	1.3895	1.3894	1.3878	1.3878
36.0	1.3938	1.3933	1.3933	1.3931	1.3915	1.3915
38.0	1.3977	1.3972	1.3971	1.3970	1.3952	1.3952
40.0	1.4017	1.4011	1.4011	1.4009	1.3989	1.3989
42.0	1.4057	1.4050	1.4050	1.4048	1.4028	1.4027
44.0	1.4098	1.4091	1.4091	1.4089	1.4066	1.4066
46.0	1.4139	1.4132	1.4131	1.4129	1.4105	1.4105
48.0	1.4181	1.4173	1.4173	1.4171	1.4145	1.4145
50.0	1.4224	1.4215	1.4215	1.4213	1.4185	1.4185
52.0	1.4267	1.4258	1.4258	1.4255	1.4226	1.4226
54.0	1.4311	1.4302	1.4301	1.4298	1.4268	1.4268
56.0	1.4356	1.4346	1.4345	1.4342	1.4310	1.4310
58.0	1.4401	1.4390	1.4390	1.4387	1.4352	1.4352
60.0	1.4447	1.4436	1.4435	1.4432	1.4396	1.4395
62.0	1.4494	1.4482	1.4482	1.4478	1.4439	1.4439
64.0	1.4542	1.4529	1.4528	1.4524	1.4484	1.4483
66.0	1.4590	1.4576	1.4576	1.4572	1.4529	1.4529
68.0	1.4639	1.4624	1.4624	1.4619	1.4575	1.4574
70.0	1.4688	1.4673	1.4673	1.4668	1.4621	1.4620
72.0	1.4739	1.4723	1.4722	1.4717	1.4668	1.4667
74.0	1.4790	1.4773	1.4773	1.4767	1.4716	1.4715
76.0	1.4842	1.4824	1.4824	1.4818	1.4764	1.4763
78.0	1.4895	1.4876	1.4876	1.4870	1.4813	1.4812
80.0	1.4948	1.4929	1.4928	1.4922	1.4863	1.4862
82.0	1.5003	1.4982	1.4982	1.4975	1.4913	1.4912
84.0	1.5058	1.5037	1.5036	1.5029	1.4964	1.4963

Refractive Index continued

Table II - Refractive Index - Commercial Corn Syrups - 45 C

D.E.	28	36	34HM	43HM	43	43IX
% Ash	0.3	0.3	0.3	0.3	0.3	0.03
D.B.						
DS						
0.0	1.3299	1.3299	1.3299	1.3299	1.3299	1.3299
2.0	1.3328	1.3328	1.3328	1.3328	1.3328	1.3328
4.0	1.3358	1.3357	1.3357	1.3357	1.3357	1.3357
6.0	1.3388	1.3388	1.3387	1.3387	1.3387	1.3387
8.0	1.3419	1.3418	1.3418	1.3418	1.3418	1.3418
10.0	1.3451	1.3450	1.3449	1.3449	1.3449	1.3449
12.0	1.3483	1.3481	1.3481	1.3480	1.3480	1.3480
14.0	1.3515	1.3514	1.3513	1.3512	1.3512	1.3512
16.0	1.3548	1.3547	1.3545	1.3545	1.3545	1.3545
18.0	1.3582	1.3580	1.3579	1.3578	1.3578	1.3578
20.0	1.3616	1.3614	1.3612	1.3611	1.3612	1.3612
22.0	1.3651	1.3648	1.3647	1.3646	1.3646	1.3646
24.0	1.3687	1.3683	1.3682	1.3680	1.3681	1.3681
26.0	1.3722	1.3719	1.3717	1.3716	1.3716	1.3716
28.0	1.3759	1.3755	1.3753	1.3752	1.3752	1.3752
30.0	1.3796	1.3792	1.3790	1.3788	1.3789	1.3789
32.0	1.3834	1.3829	1.3827	1.3825	1.3826	1.3826
34.0	1.3872	1.3867	1.3865	1.3863	1.3864	1.3864
36.0	1.3911	1.3906	1.3903	1.3901	1.3902	1.3902
38.0	1.3951	1.3945	1.3942	1.3940	1.3941	1.3941
40.0	1.3991	1.3985	1.3982	1.3979	1.3981	1.3980
42.0	1.4032	1.4026	1.4022	1.4019	1.4021	1.4021
44.0	1.4074	1.4067	1.4063	1.4060	1.4062	1.4061
46.0	1.4116	1.4109	1.4104	1.4101	1.4103	1.4103
48.0	1.4159	1.4151	1.4147	1.4143	1.4145	1.4145
50.0	1.4202	1.4194	1.4189	1.4186	1.4188	1.4188
52.0	1.4247	1.4238	1.4233	1.4229	1.4231	1.4231
54.0	1.4292	1.4283	1.4277	1.4273	1.4276	1.4275
56.0	1.4337	1.4328	1.4322	1.4318	1.4320	1.4320
58.0	1.4384	1.4374	1.4368	1.4363	1.4366	1.4366
60.0	1.4431	1.4421	1.4414	1.4410	1.4412	1.4412
62.0	1.4479	1.4468	1.4461	1.4456	1.4459	1.4459
64.0	1.4528	1.4516	1.4509	1.4504	1.4507	1.4507
66.0	1.4577	1.4565	1.4558	1.4552	1.4556	1.4555
68.0	1.4628	1.4615	1.4607	1.4601	1.4605	1.4604
70.0	1.4679	1.4665	1.4657	1.4651	1.4655	1.4654
72.0	1.4731	1.4717	1.4708	1.4702	1.4706	1.4705
74.0	1.4784	1.4769	1.4760	1.4753	1.4757	1.4757
76.0	1.4837	1.4822	1.4812	1.4805	1.4810	1.4809
78.0	1.4892	1.4876	1.4866	1.4858	1.4863	1.4862
80.0	1.4947	1.4930	1.4920	1.4912	1.4917	1.4917
82.0	1.5003	1.4986	1.4975	1.4967	1.4972	1.4972
84.0	1.5060	1.5042	1.5031	1.5023	1.5028	1.5027

Refractive Index — continued

Table 1 - Refractive Index - Commercial Corn Syrups - 45 C

D.E.	53	63	63IX	66	95	95IX
% Ash D.B.	0.3	0.3	0.3	0.3	0.3	0.03
DS						
0.0	1.3299	1.3299	1.3299	1.3299	1.3299	1.3299
2.0	1.3327	1.3327	1.3327	1.3327	1.3327	1.3327
4.0	1.3357	1.3356	1.3356	1.3356	1.3355	1.3355
6.0	1.3386	1.3386	1.3386	1.3386	1.3384	1.3384
8.0	1.3417	1.3416	1.3416	1.3416	1.3413	1.3413
10.0	1.3448	1.3447	1.3447	1.3446	1.3443	1.3443
12.0	1.3479	1.3478	1.3478	1.3477	1.3473	1.3473
14.0	1.3511	1.3509	1.3509	1.3509	1.3504	1.3504
16.0	1.3543	1.3541	1.3541	1.3541	1.3535	1.3535
18.0	1.3576	1.3574	1.3574	1.3573	1.3567	1.3567
20.0	1.3609	1.3607	1.3607	1.3606	1.3599	1.3599
22.0	1.3643	1.3641	1.3641	1.3640	1.3632	1.3632
24.0	1.3678	1.3675	1.3675	1.3674	1.3665	1.3665
26.0	1.3713	1.3709	1.3709	1.3709	1.3698	1.3698
28.0	1.3748	1.3745	1.3745	1.3744	1.3732	1.3732
30.0	1.3784	1.3780	1.3780	1.3779	1.3767	1.3767
32.0	1.3821	1.3817	1.3817	1.3816	1.3802	1.3802
34.0	1.3858	1.3854	1.3854	1.3852	1.3837	1.3837
36.0	1.3896	1.3891	1.3891	1.3890	1.3873	1.3873
38.0	1.3935	1.3929	1.3929	1.3928	1.3910	1.3910
40.0	1.3974	1.3968	1.3968	1.3966	1.3947	1.3947
42.0	1.4013	1.4007	1.4007	1.4005	1.3985	1.3985
44.0	1.4054	1.4047	1.4047	1.4045	1.4023	1.4023
46.0	1.4095	1.4087	1.4087	1.4085	1.4062	1.4061
48.0	1.4136	1.4128	1.4128	1.4126	1.4101	1.4101
50.0	1.4179	1.4170	1.4170	1.4167	1.4141	1.4141
52.0	1.4221	1.4213	1.4212	1.4210	1.4181	1.4181
54.0	1.4265	1.4256	1.4255	1.4252	1.4222	1.4222
56.0	1.4309	1.4299	1.4299	1.4296	1.4264	1.4264
58.0	1.4354	1.4343	1.4343	1.4340	1.4306	1.4306
60.0	1.4400	1.4388	1.4388	1.4385	1.4349	1.4349
62.0	1.4446	1.4434	1.4434	1.4430	1.4392	1.4392
64.0	1.4493	1.4481	1.4480	1.4476	1.4437	1.4436
66.0	1.4541	1.4528	1.4527	1.4523	1.4481	1.4481
68.0	1.4590	1.4575	1.4575	1.4571	1.4527	1.4526
70.0	1.4639	1.4624	1.4623	1.4619	1.4573	1.4572
72.0	1.4689	1.4673	1.4673	1.4668	1.4619	1.4619
74.0	1.4740	1.4723	1.4723	1.4718	1.4667	1.4666
76.0	1.4791	1.4774	1.4773	1.4768	1.4715	1.4714
78.0	1.4844	1.4826	1.4825	1.4819	1.4763	1.4763
80.0	1.4897	1.4878	1.4877	1.4871	1.4813	1.4812
82.0	1.4951	1.4931	1.4930	1.4924	1.4863	1.4862
84.0	1.5006	1.4985	1.4984	1.4978	1.4914	1.4913

Refractive Index — continued

Table III-Refractive Index - HFCS and Blends - 20 C

Product	HFCS 42	HFCS 55	HFCS 90	75% HFCS 55/25% Medium Invert	50% HFCS/50% 63DE Corn Syrup
% Ash D.B.	0.03	0.05	0.05	0.03	0.165
	1.3330	1.3330	1.3330	1.3330	1.3330
	1.3358	1.3358	1.3358	1.3359	1.3359
	1.3387	1.3387	1.3387	1.3388	1.3388
	1.3417	1.3417	1.3416	1.3417	1.3418
	1.3447	1.3447	1.3446	1.3447	1.3448
	1.3477	1.3477	1.3476	1.3477	1.3479
	1.3508	1.3508	1.3507	1.3508	1.3510
	1.3539	1.3539	1.3538	1.3539	1.3542
	1.3571	1.3571	1.3570	1.3571	1.3574
	1.3603	1.3603	1.3602	1.3603	1.3607
	1.3636	1.3635	1.3634	1.3636	1.3640
	1.3669	1.3668	1.3667	1.3669	1.3673
	1.3702	1.3702	1.3701	1.3703	1.3708
	1.3736	1.3736	1.3735	1.3737	1.3742
	1.3771	1.3771	1.3769	1.3772	1.3777
	1.3806	1.3806	1.3804	1.3807	1.3813
	1.3841	1.3841	1.3840	1.3842	1.3849
	1.3877	1.3877	1.3876	1.3879	1.3886
	1.3914	1.3914	1.3912	1.3915	1.3923
	1.3951	1.3951	1.3949	1.3953	1.3961
	1.3989	1.3988	1.3987	1.3990	1.3999
	1.4027	1.4027	1.4025	1.4029	1.4038
	1.4066	1.4065	1.4064	1.4067	1.4078
	1.4105	1.4104	1.4103	1.4107	1.4118
	1.4145	1.4144	1.4143	1.4147	1.4158
	1.4185	1.4185	1.4183	1.4187	1.4200
	1.4226	1.4225	1.4224	1.4228	1.4241
	1.4267	1.4267	1.4265	1.4270	1.4284
	1.4309	1.4309	1.4307	1.4312	1.4327
	1.4352	1.4351	1.4350	1.4355	1.4370
	1.4395	1.4395	1.4393	1.4398	1.4415
	1.4439	1.4438	1.4436	1.4442	1.4460
	1.4483	1.4483	1.4481	1.4487	1.4505
	1.4528	1.4528	1.4526	1.4532	1.4551
	1.4574	1.4573	1.4571	1.4578	1.4598
	1.4620	1.4619	1.4617	1.4624	1.4646
	1.4667	1.4666	1.4664	1.4671	1.4694
	1.4714	1.4714	1.4711	1.4719	1.4743
	1.4763	1.4762	1.4759	1.4768	1.4793
	1.4811	1.4811	1.4808	1.4817	1.4843
	1.4861	1.4860	1.4857	1.4867	1.4894
	1.4911	1.4910	1.4907	1.4917	1.4946
	1.4962	1.4961	1.4957	1.4968	1.4998

Refractive Index — continued

Table III-Refractive Index - HFCS and Blends - 45 C

Product	HFCS 42	HFCS 55	HFCS 90	75% HFCS 55/25% Medium Invert	50% HFCS/50% 63DE Corn Syrup
% Ash D.B.	0.03	0.05	0.05	0.03	0.165
	1.3299	1.3299	1.3299	1.3299	1.3299
	1.3326	1.3326	1.3326	1.3326	1.3327
	1.3355	1.3354	1.3354	1.3355	1.3355
	1.3383	1.3383	1.3382	1.3383	1.3385
	1.3412	1.3412	1.3411	1.3413	1.3414
	1.3442	1.3441	1.3440	1.3442	1.3444
	1.3472	1.3471	1.3470	1.3472	1.3475
	1.3502	1.3502	1.3500	1.3503	1.3506
	1.3533	1.3533	1.3531	1.3534	1.3537
	1.3565	1.3564	1.3562	1.3565	1.3569
	1.3597	1.3596	1.3594	1.3597	1.3602
	1.3629	1.3628	1.3626	1.3630	1.3635
	1.3662	1.3661	1.3658	1.3663	1.3668
	1.3695	1.3694	1.3692	1.3696	1.3702
	1.3729	1.3728	1.3725	1.3730	1.3737
	1.3764	1.3763	1.3759	1.3765	1.3772
	1.3798	1.3797	1.3794	1.3800	1.3807
	1.3834	1.3833	1.3829	1.3835	1.3843
	1.3870	1.3869	1.3865	1.3871	1.3880
	1.3906	1.3905	1.3901	1.3908	1.3917
	1.3943	1.3942	1.3938	1.3945	1.3955
	1.3981	1.3979	1.3975	1.3982	1.3993
	1.4019	1.4017	1.4013	1.4021	1.4032
	1.4057	1.4056	1.4051	1.4059	1.4072
	1.4096	1.4095	1.4090	1.4099	1.4112
	1.4136	1.4134	1.4130	1.4139	1.4153
	1.4176	1.4175	1.4170	1.4179	1.4194
	1.4217	1.4215	1.4210	1.4220	1.4236
	1.4259	1.4257	1.4251	1.4262	1.4278
	1.4301	1.4299	1.4293	1.4304	1.4321
	1.4343	1.4341	1.4335	1.4347	1.4365
	1.4386	1.4384	1.4378	1.4390	1.4410
	1.4430	1.4428	1.4422	1.4434	1.4455
	1.4475	1.4472	1.4466	1.4479	1.4500
	1.4520	1.4517	1.4510	1.4524	1.4547
	1.4565	1.4563	1.4556	1.4570	1.4594
	1.4612	1.4609	1.4602	1.4617	1.4642
	1.4659	1.4656	1.4648	1.4664	1.4690
	1.4706	1.4704	1.4695	1.4712	1.4739
	1.4755	1.4752	1.4743	1.4761	1.4789
	1.4804	1.4801	1.4792	1.4810	1.4840
	1.4854	1.4850	1.4841	1.4860	1.4891
	1.4904	1.4901	1.4891	1.4911	1.4943

Refractive Index — continued
Table V

Ash and DE Corrections

Changes in Refractive Index for an increase of:

% Dry Substance	1% Ash	D.E.
2	0.000000	-0.000001
4	0.000000	-0.000003
6	0.000001	-0.000005
8	0.000002	-0.000007
10	0.000003	-0.000010
12	0.000004	-0.000012
14	0.000006	-0.000015
16	0.000008	-0.000017
18	0.000010	-0.000020
20	0.000013	-0.000023
22	0.000016	-0.000026
24	0.000019	-0.000029
26	0.000022	-0.000033
28	0.000026	-0.000036
30	0.000030	-0.000040
32	0.000034	-0.000044
34	0.000039	-0.000048
36	0.000044	-0.000052
38	0.000049	-0.000057
40	0.000055	-0.000061
42	0.000061	-0.000066
44	0.000068	-0.000071
46	0.000074	-0.000076
48	0.000082	-0.000081
50	0.000089	-0.000087
52	0.000097	-0.000093
54	0.000105	-0.000099
56	0.000114	-0.000105
58	0.000123	-0.000112
60	0.000133	-0.000118
62	0.000143	-0.000125
64	0.000153	-0.000132
66	0.000164	-0.000140
68	0.000175	-0.000147
70	0.000187	-0.000155
72	0.000199	-0.000163
74	0.000212	-0.000172
76	0.000225	-0.000181
78	0.000239	-0.000190
80	0.000253	-0.000199
82	0.000268	-0.000208
84	0.000283	-0.000218

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ACKNOWLEDGEMENTS

The update of this program and reconciliation of the program's physical data would not have been possible without the efforts of John Rasche, formerly of A. E. Staley Manufacturing Company and now a consultant to the Corn Refiners Association, Inc. Tom Gagnon of A. E. Staley Manufacturing Company was instrumental in the creation of the Microsoft Excel ®-based program. CRA would also like to extend a special thanks to Jerry Geske, also of A. E. Staley Manufacturing Company, for his assistance with the program's development and data reconciliation.

The development of the extensive physical data, mathematical relationships and computer program which are represented in the original RI-DS program provided the foundation for the update, and was made possible by a wide variety of personnel in the corn refining industry and academia. CRA would like to thank the following for their work on the original data:
Anna Wartman; Robert J. Smith; Sharon Purvis; Earl Engel; Frank Kurtz; Raffaele Bernetti; Kenny Brobst; Larry Fitt; and Ki Park.