



OFFICE OF
BUILDING TECHNOLOGY,
STATE AND COMMUNITY PROGRAMS

Review of Survey Data to Support Revisions to DOE's Dishwasher Test Procedure

Addendum

**U.S. Department of Energy
Energy Efficiency and
Renewable Energy
Office of Building Technology,
State and Community Programs
1000 Independence Avenue, SW
Washington, DC 20585**

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**Arthur D. Little, Inc.
Acorn Park
Cambridge, MA 02140**

Addendum

The prime objective of this addendum is to expand on and readdress two areas of the report, “*Review of Survey Data to Support Revisions to DOE’s Dishwasher Test Procedure*”, prepared for the Department of Energy’s Office of Building Technology, State and Community Programs and issued December 18, 2001. These areas are:

1. To provide more detail on the analysis in the section, *Quantitative Amount of Soil in a Dishwasher Load*,
 - a) Demonstrating the robustness of the prime source of data for the analysis – survey C,
 - b) Introducing and analyzing additional data from survey C, and
 - c) Refocusing on survey C as the primary basis for determining the portion of the AHAM DW-1 soil load that could be used to represent light, medium, and heavy soil levels; and
2. To clarify the rationale for the recommended 200 to 233 average-use cycles per year for a dishwasher.

Background on the Quantitative Amount of Soil in a Dishwasher Load

This section of the report drew from three surveys identified as Survey C, Survey D, and Survey F. Manufacturers and energy interest groups provided these surveys. As in the report, a key requirement of this addendum is to maintain the confidentiality of the industry survey sources. To this end no source is identified and only general information on the data source is provided. Table 1 gives a comparative overview of the scope and size of these three surveys.

Table 1 – Overview of scope and size of surveys

Survey Identifier	Scope	Number of Households	Breadth of Information	Quality of Information
Survey C	Nationally Representative	< 1,000	Wide	High
Survey D	Regional	> 1,000	Limited	Moderate
Survey F	Regional	< 250	Moderate	Moderate

Surveys C, D, and F, cumulatively representing over 2,000 U.S. households, provide text and/or graphic descriptions to link their categories of the level of soil to the three soil levels – Light, Medium, Heavy- and to quantitative amounts of soil for each level. Referencing ANSI/AHAM Standard DW-1 for the types of soil and, most importantly, the amounts of soil is essential in relating each of the three soil levels to an amount of soil.

The relationship to the amounts of soil representative of the soil levels is derived differently for each survey, but for each survey the relationship is made in terms of the number of place settings in the DOE test load that are soiled according to ANSI/AHAM Standard DW-1. The results of the analysis to determine these relationships were presented in the report issued on December 18, 2001, and reflect an aggregation of the data from surveys C, D, and F.

Detail on the Analysis of Quantitative Amount of Soil in a Dishwasher Load

The following sections describe in detail how the relationships between representative amounts of soil in a dishwasher load and the number of place settings in the DOE test load that are soiled according to ANSI/AHAM DW-1 were developed for surveys C, D, and F.

Survey C

The authors of survey C determined representative amounts of soil in a dishwasher load using an extensive set of photographs taken by consumers in their households of the soiled dishware in their dishwasher. The data set of survey C includes photos of both the lower and upper rack of dishware for 5,849 cycles distributed across nearly 1,000 U.S. households nationwide. Because of this photographic data and other substantial data sets Survey C is considered the most robust and credible source of information to determine the amount of soil on the dishware in the dishwashers of U.S. households.

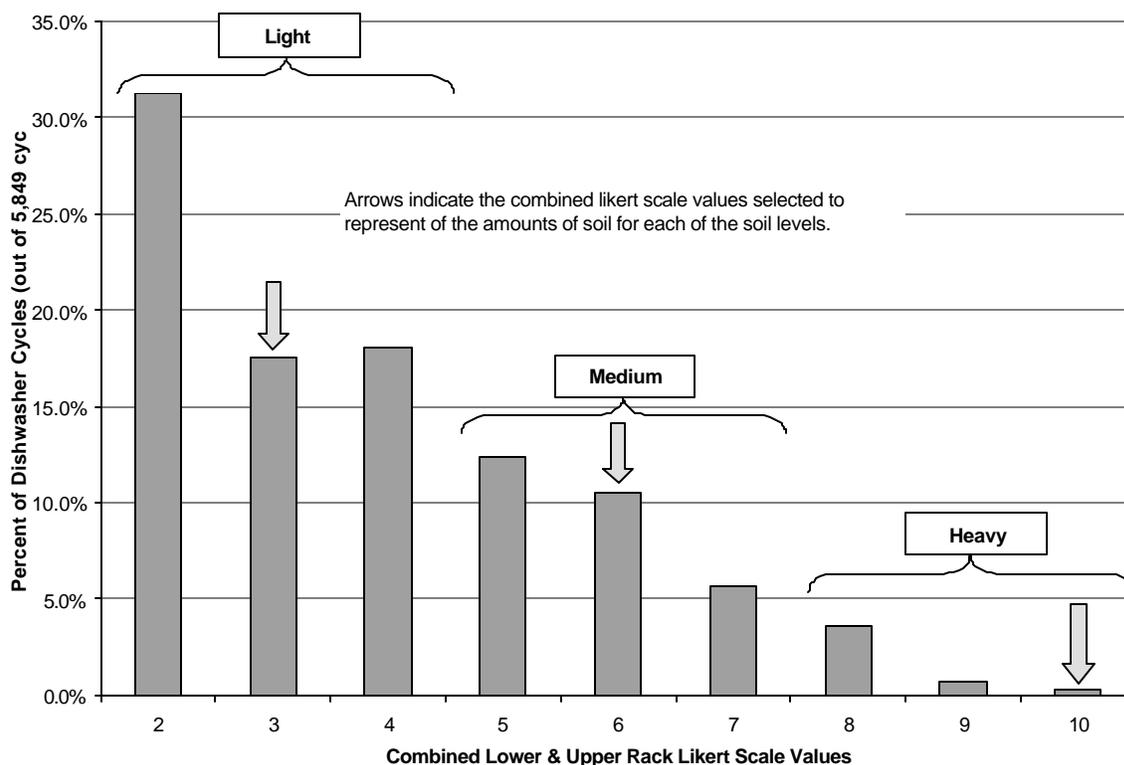
In preparation of the report of December 18, 2001, the authors of survey C provided the results of their soil level analysis and a brief overview of their survey approach, photographic data, and soil level analysis. To prepare the following discussion on their analysis of quantitative amounts of soil in a dishwasher load, the authors of survey C provided additional detail information. Given this additional information, a later section of this addendum refocuses the analysis and results presented in the report of December 18, 2001 to consider only survey C.

The authors of survey C assessed their photographic data by first establishing a Likert scale¹ to compare and rank each photo. Their Likert scale has five levels for the lower rack and five levels for the upper rack. Images of their Likert scale are shown in the appendix.

This assessment resulted in the distribution shown in Figure 1. The x-axis in Figure 1 runs from a value of 2 to a value of 10 and represents the combined value of the Likert scale rankings for the lower and upper racks for each dishwasher load. For example, if the lower rack of a dishwasher load ranked a 3 and the upper rack a 1, it has a combined value of 4. The authors clustered the combined values into three levels – Light, Medium, and Heavy. The combined values of 2, 3, and 4 were categorized as light. The combined values of 5, 6, and 7 were categorized as medium. The combined values of 8, 9, and 10 were categorized as heavy.

¹ Likert scale – A response scale, developed by Rensis Likert, used for assessing opinions and usually consisting of 5 or more categories. As a semi-variable approach it provides more information than the simple attribute (yes-no) question.

Figure 1 – Distribution of Survey C results along its combined Likert scale



A single combined value was selected from each soil level to facilitate more detailed evaluation and quantification of the photographic data to determine the amounts of soil representative of each soil level. For the light level the selected combined value was 3. For the medium level the selected combined value was 6. For the heavy level the selected combined value was 10. On review of Figure 2, it is clear that the combined values selected to represent the three soil levels – Light, Medium, and Heavy – were conservative choices. The selection of the combined value of 10 to represent the heavy level was particularly conservative. Out of the 5,849 dishwasher cycles evaluated, only 18 cycles were found to rank a combined value of 10.

Approximately 12 sets of photos for each of the selected combined values were analyzed by a professional home economist. The home economist estimated the types and amounts of the food soils shown in the photos. The home economist then expressed these estimates in terms of amounts of food soils listed in ANSI/AHAM Standard DW-1. With the amount of soil expressed in terms of DW-1 food soils, a corresponding number of place settings that could be soiled per DW-1 with that amount of food soil was easily determined. The results of this analysis are shown in Table 2.

Table 2 – Results of survey C

Soil Level	Light	Medium	Heavy
Combined Likert Scale Ranking	3	6	10
Number of Place Settings in DOE Test Load Soiled per DW-1	≤ 1/2	~ 2	< 5 *

* Of the 19 dishwasher cycles that ranked a 10 on the combined Likert scale, only 2 approached the quantity of food soil of 5 DW-1 soiled place settings.

Survey D

For survey D the respondents directly select an amount of soil in terms of DW-1 soiled place settings. At a central testing location the authors of survey D set up 6 images of a DW-1 place setting. Table 3 describes the 6 images of a place setting, increasingly soiled according to DW-1, shown to survey respondents.

Table 3 – Description of the 6 images of a DW-1 soiled place setting shown to respondents in survey D

Image Identifier	Description	Associated Soil Level assigned by Arthur D. Little	Corresponding Number of Soiled Place Setting in DOE Test Load
1	Clean	Light	0
2	25% of DW-1 food soils rinsed with water		1
3	25% of DW-1 food soils		2
4	50% of DW-1 food soils	Medium	4
5	75% of DW-1 food soils		6
6	100% of DW-1 food soils	Heavy	8

Also shown in Table 3 is how Arthur D. Little grouped the six images to the three soil levels – Light, Medium, and Heavy, and associated the images to a corresponding number of DW-1 soiled place settings in the DOE test load. Arthur D. Little’s grouping of the six images was conducted in light of all of the available survey information and represents Arthur D. Little’s best judgement.

Grouping image 1 (Clean) with the light soil level, image 4 (50% DW-1) with the medium soil level, and image 6 (100% DW-1) with the heavy soil level was straightforward. Judgement entered in grouping the 3 remaining images. Image 2 (25% DW-1 rinsed) showed very little soil and clearly belonged in the light soil level. Image 3 (25% DW-1) appeared substantially less soiled than image 4 and was grouped with the light soil level. Similarly, image 5 (75% DW-1) appeared only somewhat heavier soiled than image 4 and substantially less soiled than image 6, and was grouped with the medium soil level.

Associating the images to a corresponding number of DW-1 soiled place settings in the DOE test load was very direct. Given that there are 8 place settings in the DOE test load, the corresponding number of DW-1 soiled place settings is the product of 8 place settings times the percentage of DW-1 soil. In the case of image 2 (25% DW-1 rinsed), the corresponding number of DW-1 soiled place settings in the DOE test load was arrived at by splitting the difference between that for image 1 (Clean) and image 3 (25% DW-1).

Examples of the images used in survey D are shown in Figure 2.

Figure 2 – Examples of the images of a DW-1 soiled place setting used in survey D



The authors interviewed respondents and asked them to select the image that most closely represents the level of soil on the dishware in their dishwasher. The results of survey D distributed as shown in Table 4

Table 4 – Results of survey D

Level of Soil on the Dishware in the Dishwasher					
Light			Medium		Heavy
Clean	25% DW-1 Rinsed	25% DW-1	50% DW-1	75% DW-1	100% DW-1
13.4%	24.1%	24.1%	11.2%	10.2%	17.0%

As discussed in the report, the authors of survey D noted that some number of respondents were not properly interviewed and instructed prior to their selection of one of the soiled place setting images. The authors suspected that because of this lack of instruction respondents may have selected an image based on that image representing the amount of food soil in their dishwasher, rather than, as desired, selecting the image that most closely represents the level of soil on the dishware in their dishwasher.

Survey F

For survey F, Arthur D. Little linked the survey’s description of its soil categories to an amount of soil in terms of DW-1 place settings. The authors of survey F generated 4 categories of soil level. Brief descriptions of those four categories were presented to the survey respondents. Table 5 describes the four categories of soil level used in survey F. and Arthur D. Little’s assessment of the relation to the three soil levels – Light, Medium, and Heavy, and a corresponding number of DW-1 soiled place settings in the DOE test load.

Table 5 – Description of the categories of soil level used in survey F

Category Identifier	Category Description	Associated Soil Level assigned by Arthur D. Little	Corresponding Number of Soiled Place Setting in DOE Test Load
Very Clean	All or almost all food gone	Light	1
Somewhat Clean	Small particles of food left		
Somewhat Dirty	Only the largest chunks of food gone	Medium	4
Very Dirty	No or almost no food removed	Heavy	8

Table 5 also shows how Arthur D. Little grouped the four categories of survey F to the three soil levels – Light, Medium, and Heavy, and associated the category descriptions to a corresponding number of DW-1 soiled place settings in the DOE test load. Arthur D. Little’s grouping of the four

categories was conducted in light of all of the available survey information and represents Arthur D. Little's best judgement.

Grouping the Very Clean category with the light soil level and the Very Dirty category with the heavy soil level was straightforward. Here, judgement entered in grouping the 2 remaining categories. The Somewhat Clean category implied very little soil and clearly belonged in the light soil level. The Somewhat Dirty category implied much more food soil than the Somewhat Clean category, but substantially less soiled than the Very Dirty category, and was grouped in the medium soil level.

Associating the categories to a corresponding number of DW-1 soiled place settings in the DOE test load was less direct. Instead the soil levels were assigned a corresponding number of DW-1 soiled place settings. Given that there are 8 place settings in the DOE test load, the light soil level was assigned 1 DW-1 soiled place setting, the medium level – 4 DW-1 soiled place settings, and the heavy level – 8 DW-1 soiled place settings.

The results of survey F are shown in Table 6.

Table 6 – Results of survey F

Level of Soil on the Dishware in the Dishwasher			
Light		Medium	Heavy
Very Clean	Somewhat Clean	Somewhat Dirty	Very Dirty
25.0%	38.0%	33.0%	4.0%

Summary of Analysis on Quantitative Amount of Soil in a Dishwasher Load

The following tables and figure result directly from the review and analysis of surveys C, D, and F outlined above. These tables and figure were discussed and presented in the report of December 18, 2001. They are presented here again for clarity in demonstrating the progression of the detailed analysis to the results in the report of December 18, 2001. In the following section the analysis and results will be reconsidered in light of the additional information provided by the authors of survey C for this addendum.

Table 7 is the consolidation of the data found in Tables 2, 4, and 6. Figure 3 is the distribution of that data weighted by the number of survey respondents. Table 8 shows the weighted averages of the distribution shown in Figure 3 for each of the three soil levels – Light, Medium, and Heavy.

Table 7 – Range of Survey Data on the Representative Amounts of Soil in the Three Soil Levels

	Soil Amounts in terms of Place Settings Soiled Per DW-1		
	Light	Medium	Heavy
Survey C	½	2	5
Survey D	1-2	4-6	8
Survey F	1	4	8

Figure 3 – Distribution of Survey Respondents on Representative Amounts of Soil in Each of the Three Soil Levels

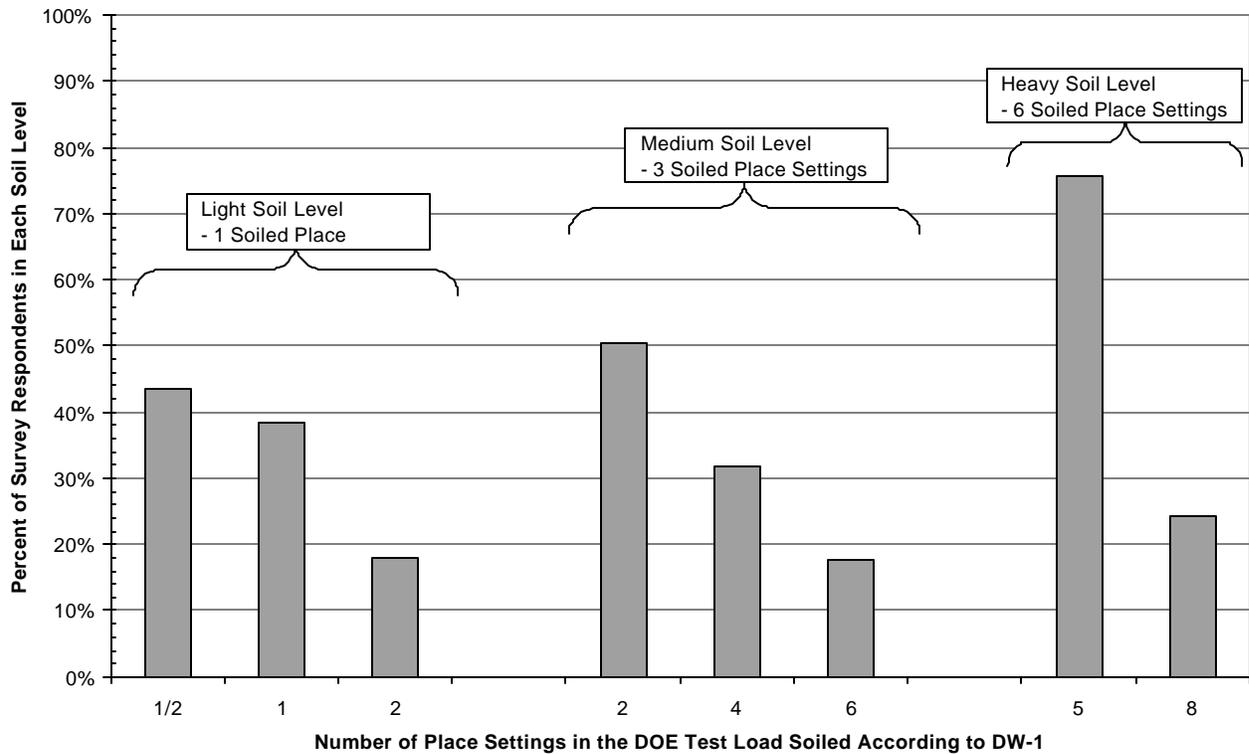


Table 8 – Representative Amounts of Soil in Each of the Three Soil Levels Found in Dishwashers of U.S. households

Soil Amounts in terms of Place Settings Soiled Per DW-1			
	Light	Medium	Heavy
Weighted Average	1	3	6

Additional Data from Survey C and Refocus of Analysis on Survey C

In the preparation of the report issued December 18, 2001 the authors of survey C provided only the results of their analysis – the number of place settings in the DOE test load soiled per DW-1 as shown in Table 2, and only a brief description of their approach to the analysis. In preparation of this addendum the authors of survey C provided a substantial amount of additional information to fill in the detail of their analysis. This additional information includes their Likert scale (Appendix), the ranking of their data against that Likert scale (Figure 1), and a professional home economist’s evaluation of the amount of soil shown in samples of the photographic data taken from the combined Likert scale rankings of 3, 6, and 10. This section presents the evaluation of the professional home economist of survey C and reconsiders the results of that evaluation.

Recall from the discussion above on survey C that the authors of survey C grouped their combined Likert scale rankings into three soil levels – Light, Medium, and Heavy. The combined Likert scale rankings of 2, 3, and 4 were grouped into the light soil level. The combined Likert scale rankings of 5, 6, and 7 were grouped into the medium soil level. The combined Likert scale rankings of 8, 9, and 10 were grouped into the heavy soil level. The combined Likert scale rankings of 3, 6, and 10 were selected to represent the light, medium and heavy soil level, respectively.

A professional home economist analyzed a number of sets of photos for each of the combined Likert scale rankings of 3, 6, and 10. The home economist estimated the types and amounts of food soils shown in the photos. Table 9 lists the averages and medians of the mass of food soils estimated from the samples of photo sets for the possible Likert scale combinations corresponding to the combined Likert scale rankings of 3, 6, and 10.

Table 9 – Averages and medians of the mass of food soils estimated by a home economist

Soil Level	Associated Combined Likert Scale Ranking	Possible Likert Scale Combinations (Lower/Upper)	Number of Photo Sets Analyzed	Average Mass of Food Soil (grams)	Median Mass of Food Soil (grams)
Light	3	2/1	10	12.7	10.85
Medium	6	3/3	9	27.0	24.9
		4/2	10	52.3	50.25
		5/1	10	72.3	62.5
Heavy	10	5/5	18	109.5	115.8

Translating these masses of food soils to corresponding numbers of place settings soiled according to ANSI/AHAM DW-1 is readily done given that DW-1 specifies approximately 31.3 grams of food soils per place setting as shown in Table 10.

Table 10 - Averages and medians of the number of DW-1 soiled place settings based on the estimated masses of food soils in Table 9

Soil Level	Associated Combined Likert Scale Ranking	Possible Likert Scale Combinations (Lower/Upper)	Number of Photo Sets Analyzed	Average Number of DW-1 Soiled Place Settings	Median Number of DW-1 Soiled Place Settings
Light	3	2/1	10	0.41	0.35
Medium	6	3/3	9	0.86	0.80
		4/2	10	1.67	1.61
		5/1	10	2.31	2.00
Heavy	10	5/5	18	3.50	3.70

Comparing Table 10 to the results initially provided by the authors of survey C in Table 2 further indicates the conservatism of the authors in interpreting the results of their analysis. Discussions with the authors of survey C indicated that the average number of DW-1 soiled place settings in Table 10 were rounded up to yield the results that they had reported in Figure 2. However, their reported value of <5 DW-1 soiled place setting for the heavy soil level seems inconsistent with simple rounding upward of the averages for the number of DW-1 soiled place settings. It appears more consistent with a value that represents an extreme bound. This inconsistency is addressed in the following recommendations.

Clarification on the Recommended Range of Average-use Cycles per Year

The report of December 18, 2001 presented three approaches to establish a number for the average-use cycles per year of a dishwasher. The first approach referenced the Energy Information Administration's 1997 Residential Energy Consumption Survey (1997 RECS) as a large, well-documented, and publicly available study on the average-use of a dishwasher. Although a large and well-documented survey, 1997 RECS use of only three response categories, two of which were unbounded, made determining an average number difficult. The 1997 RECS data on average-use of a dishwasher did clearly indicate that 50 percent of its respondents use a dishwasher 4 or less times per week, or approximately 208 times per year. The 1997 RECS set a target area for the number of average-use cycles per year.

The second approach considered five nationally representative surveys (surveys A, B, G, H, and 1997 RECS) using consistent definitions for the broad or unbounded categories of the surveys'. A low value, an average value, and a high value were defined for each category found in the surveys. These values were used to calculate three averages for each survey – one average using the low values, a second average using the 'average' values, and a third average using the high values. As presented in the report of December 18, 2001 the averages of these averages were 180 for the low values, 206 for the average values, and 233 for the high values. This approach produced averages centered near the target area set by 1997 RECS and established a range, although broad, for the number of average-use cycles per year.

The third approach narrowed the range for the number of average-use cycles per year by building on the previous approaches. The first approach using the 1997 RECS data set a target area for the number of average-use cycles per year. The second approach produced averages centered on this target area and suggested that all of the available data pointed to this target area. The third approach used a weighted average to test whether the relative sizes of the five surveys would skew the averages from the target area. Using the average values for the categories of the five surveys from the second approach, an average weighted by the number of respondents in each survey was calculated. This calculation yielded a weighted average of 200 average-use cycles per year. As this weighted average of the five nationally representative surveys, was near the target area and near the middle of the previously calculated range of averages, it indicated that the size of no one survey dominated over the others. This weighted average became the new minimum of the range for the number of average-use cycles per year. Therefore, the lower end of the broad range established in the previous approach moved up from 180 to 200 average-use cycles per year.

The above analyses of available survey data on the frequency of households' usage of a dishwasher set a range for the number of average-use cycles per year. The lower end of this range, 200, was set by the third approach and the upper end of this range, 233, remained at the high average set by the second approach. To refine this recommended range further additional data for the representative average-use cycles per year was sought from the dishwasher detergent industry. This additional data was anticipated for late December 2001 or early January 2002, however no additional data has been made available to augment the recommendation.

Recommendations

Given the depth of the additional information provided by the authors of survey C and the detail of the analysis of survey C presented in this addendum, it is Arthur D. Little's recommendation that the data of survey C stand as the basis for determining the amount of soil on dishware in the dishwashers of U.S. households. However, Arthur D. Little also recommends that the survey C results reported in Table 2 should be modified to more closely reflect the approach of rounding upward the average number of DW-1 soiled place settings in Table 10. To this end the number of DW-1 soiled place settings corresponding to the heavy soil level should be set equal to 4. Table 11 displays the number of DW-1 soiled place settings reported by the authors of survey C and highlights the modified number of place settings recommended by Arthur D. Little on review of greater detail from survey C.

Table 11 – Revised recommendation on the number of DW-1 soiled place settings corresponding to the soil levels

Soil Level	Light	Medium	Heavy
Number of Place Settings in DOE Test Load Soiled per DW-1 report by the authors of survey C	$\leq 1/2$	~ 2	< 5
Number of Place Settings in DOE Test Load Soiled per DW-1 recommended by Arthur D. Little on detailed review of survey C	1/2	2	4

To be consistent with the recommendation to let survey C stand as the basis for determining the amount of soil on dishware in the dishwashers of U.S. households, it is important to revisit the distribution of U.S. households by the level of soil in dishwasher loads (December 18, 2001 report, Figure 2). In the report of December 18, 2001 this distribution was based on an aggregation of surveys A and C. As discussed in the report both surveys A and C are large, nationally representative surveys and both present very similar data on the qualitative level of soil in dishwasher loads. Taking survey C alone would shift this distribution somewhat from the medium soil level to the light soil level. However, ignoring survey A would be discounting a quality survey. Therefore, Arthur D. Little further recommends that the distribution of U.S. households by the level of soil in dishwasher loads should stand as it was presented in the report of December 18, 2001.

Appendix – Survey C Likert scale

1



2



3



4



5

