Performance of coated fuel drums subjected to long-term storage

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PERFORMANCE OF COATED FUEL DRUMS SUBJECTED TO LONG-TERM STORAGE

by

H. E. Ashton

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PREFACE

This is the final report concerned with the performance of organic coatings on fuel storage drums. It gives the evaluation of the interior and exterior coatings after 7 and $10\frac{1}{2}$ years exposure. Because of the complexity of the experiment, preparation of the report was delayed. The effect of storage on the fuels was discussed in reports issued by the Division of Mechanical Engineering in 1965 and 1969.

Based on the evaluations, recommendations are made for internal finishing systems for long and short term storage of fuels in steel drums. Treatments and coatings for the exterior of the drums are also discussed.

The project was initiated by a committee composed mostly of National Research and National Defence staff; personnel who were members of the committee at various times are listed in the final appendix. The selection and preparation of the coatings, manufacture and filling of the drums, and field examinations were carried out under the supervision of Mr. John Harris. Mr. E. V. Gibbons prepared the first report covering the above work and the first examination of emptied drums. Mr. H. E. Ashton, the author of this report, supervised the final examinations and analyzed the results. Mr. R. C. Seeley carried out all examinations, both at the exposure site and in the laboratory, and maintained records of the project.

Ottawa
December, 1971.

N. B. Hutcheon,
Director.

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by

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The reasons for studying pretreatment and coating systems for use in fuel storage drums were discussed in the interim report prepared by Gibbons (1). The present report will describe the results of the second and third examinations of the drums and will give conclusions based on the complete exposure study. Most emphasis will, however, be placed on the results from the longer exposures. Because the primary objective was to be able to store fuel for long periods without deleterious effect on it, most attention will be paid to the interior finishes which were in contact with the fuel. The durability of the exterior coatings is more related to appearance unless corrosion should be so severe as to lead to penetration of the drum from the outside.

EXPERIMENTAL

The types of coatings and metal pretreatments and the numbers assigned to each combination of fuel and finishing system were described in the previous report. The drums remaining after the first examination were kept on their sides on wooden racks at the Ottawa exposure site of the Division of Building Research. The extra empty drums were left standing on end on adjacent ground as shown in Fig. 1 of the previous report.

For the second examination one drum was selected at random from each group in November 1964. After the fuels were sampled and removed, the drums were thoroughly drained and washed to remove traces of fuel and the tops cut out as before. A few of the spare drums had the tops inadvertently removed, so they were included in the inspection of the test drums. The open drums were then placed in a large laboratory so that winter weather would not affect the thoroughness of the subsequent examination. The condition of the interior of the drums was first noted by the same observer who made the 1962 examination. After recording the description of the drums, the observer rated each on the 0-10 scale, where 10 is no change from the original and 0 is complete failure.

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(1) Gibbons, E. V. "Behaviour of Organic Coatings on Hydrocarbon Fuel Storage Drums - A Progress Report," DBR Internal Report No. 292. April 1964.

The drums were then rated by the author, with emphasis placed on consistency of rating by frequent comparisons of drums with the same and adjacent ratings. The two sets of ratings were reviewed and differences resolved by mutual examination and discussion. The complete descriptions of the drums and the final ratings are given in Appendix A. The rating results are summarized in Table I. The same procedure was followed for the exterior of the drums and the results appear in Appendix B and Table XIV.

The third and final examination was scheduled for the fall of 1967 at the end of ten years exposure. At this time there were only four drums for each finishing system because the two filled with automotive combat gasoline (3-GP-7b) had been removed in 1962 and 1964. As the fuels and Lubricants Laboratory of the Division of Mechanical Engineering was not able to sample the fuels before the onset of winter, the emptying and preparation of the drums was delayed until the summer of 1968. The examination and rating of the opened drums were carried out as before in August and September of that year. Again, some of the spare drums were examined. The description of the drum conditions is given in Appendix C and the ratings are summarized in Table II.

RESULTS OF INTERIOR EXAMINATIONS

Method of Analysis - The 1964 ratings of the interior condition of the drums are presented in Table I. It is apparent that there are differences in performances between coatings but that there are greater differences within the same coating depending upon the other factors - treatment, fuel and water. This type of experiment requires statistical evaluation to determine whether the observed differences are significant and to find which factors are most important.

Upon examination it is found that this experiment is, unfortunately, not balanced with regard to several of the factors. Water was added to only two of the three fuels so that all the results cannot be compared at one time. In trying to establish the effect of fuel on coating performance, either the third fuel or the two to which water was added have to be disregarded. In finding out the effect of water, results with the third fuel must be discounted.

Surface treatment is another unbalanced factor. Half the drums had one treatment, one quarter had a second and the remaining quarter a third treatment. This means that every coating system was not applied over every metal pretreatment. Consequently, it is only possible to determine whether treatments are affected by other factors, such as water, by dividing the results into two groups. In addition, it is not possible to decide whether a coating might have performed better over a treatment on which it was not applied. Fuels also were not equally divided between the drums. Automotive combat gasoline was only placed in two drums of each

group. The 1964 results for the automotive gas have, therefore, to be dropped when making comparisons between the 1964 and 1968 examinations.

Finally, there was no replication, i.e., more than one drum treated exactly the same for each factor in each examination year. As a result the statistical parameter, "degrees of freedom", is spread over each examination making it almost impossible to prove statistically that any one factor is significant, in spite of the large number of drums used in the complete experiment.

The effect of these deficiencies in the experimental design is to make the statistical analysis very complicated, because it has to be done in sections, and to reduce its sensitivity markedly. The final conclusions are thus less reliable than might be desired. These factors were apparently realized for the first time after the 1964 examination and it was then decided not to issue an interim report but to wait until the end of the exposure test. It was hoped that the results for the two examinations would not differ greatly in order of performance so that more definite conclusions could be reached. Issue of this final report has also been delayed because of the complex statistical analyses required.

1964 Interior Results - The statistical treatment using as many ratings as possible at any one time is an analysis of variance with the metal treatments "nested" in the coatings. In order to include the effect of water, the automotive gas results have to be omitted from the fuel factor. Hence, 48 of the total of 60 ratings in Table I were used. The summary of this analysis is given in Table III.

The analysis shows that water is the most significant factor, followed by coatings. There is also a significant interaction between coatings and water, which means that the performance of some coatings is affected, usually adversely, by the presence of water while that of others is not. There is no significant difference between the three treatments or the two fuels. Because of the experimental design it is not possible with this analysis to show whether treatments or fuels are affected by the addition of water.

To obtain information on the interaction of treatments with other factors, the 48 results used in the previous analysis were divided into two groups: coatings 1, 5 and 6, which were applied over wash primer and phosphate pretreatments, and coatings 2, 3 and 4, for which the steel had been phosphated or degreased. The results of the two analyses are given in Tables IV and V.

From them it can again be seen that water and coatings are the most important factors. There is a significant difference between phosphate and degreasing, but the difference between wash primer and phosphate is less conclusively established. With the latter two treatments there was a difference between the two fuels but not with the first pair of treatments. In both groups, the performance of coatings was affected by water. There

was only a significant interaction between treatments and water in the phosphate-degreasing group. This occurred because the performance of coatings on degreased steel was greatly impaired when water was present in the drum.

The other way to subject the 1964 results to an analysis of variance is to compare the three fuels simultaneously. To do this it is necessary to omit the ratings of the two fuels when water was added. Hence, only 60 per cent of the results can be used in the analysis which is summarized in Table VI. The conclusions are that without water there are no significant differences between coatings or between treatments and no significant interaction between coatings and fuels. The latter means that one coating did not perform better in one fuel than in another. Differences between fuels are significant only at the 95% level; i.e., there is one chance in 20 that the differences are not significant.

The ratings can also be statistically analyzed in a different manner, the results of which are more easily comprehended than the analysis of variance. This method, called the control chart procedure, is based on comparing means and ranges of replicate samples. Since there was no replication in this experiment it is necessary to select the least significant factor and treat combinations where it is the only variable as pairs or trios.

In Table VI it was shown that treatment was the least significant factor when the results for three fuels without water were analyzed. These ratings were, therefore, summed across treatments and the mean range for pairs and the mean rating calculated for each fuel and for the combined results. The values obtained are presented in Table VII. From the appropriate range, the limits within which both the mean and range of a pair of values should fall can be calculated at the confidence levels — 3σ (99.73%), 99% and 95%. The formulas are:

$$\text{Upper Control Limit for Range} = D_4(\bar{R} \text{ or } \bar{\bar{R}})$$

$$\text{Control Limits for Mean} = \pm A_2(\bar{R} \text{ or } \bar{\bar{R}})$$

where A_2 and D_4 are factors depending upon the number of values in the set and the confidence level. The larger the range or the higher the confidence level, the wider the limits which must be exceeded before it can be proved that a value does not belong to a group under consideration. (In control chart terminology, the process is "out of control" when values exceed the limits).

The results for the 1964 ratings without water are plotted in Figure 1. This gives some indication why the analysis of variance showed the fuels to be statistically different at the 95% level: the mean for avgas is somewhat

higher than that of jet fuel, which in turn is higher than the automotive gas. However, the range or lower portion of the graph indicates that the differences may be due in part to two anomalous results with the automotive gas. Coating 1 has a range of 5.5, which exceeds the limits, calculated on the over-all mean range ($\bar{R}$), within which 99.73% of all ranges should fall. Coating 3 has a range of 8, which exceeds not only these limits but also the 95% limits calculated from the mean range for automotive gas alone. Figure 1 shows that the means of these two coatings are correspondingly depressed. Hence, the two ratings which caused the low means and high ranges appear to be "wild", i.e. not truly representative of the performance to be expected of the coating pretreatment system exposed to automotive fuel. By contrast, the low mean of coating 5 in jet fuel is not associated with a high range. Because the mean is lower than the 3σ control limits calculated both from the grand mean and range and from the jet fuel mean and range, it is considered to be a truly divergent value. The performance of coating 5 in jet fuel is, therefore, poorer than the other coatings.

If the two individual ratings which caused coatings 1 and 3 to have high ranges in automotive gas are deleted, the fuel mean range (which was calculated with the suspect values) can be used to provide two substitute ratings. For example, instead of ratings of 10 and 2, coating 3 would have 10 and 10-3 = 7. Its mean rating would then be more similar to that of coating 4 as it was with the other two fuels. The mean for the auto gas recalculated on this basis is increased to 8.04, which is very close to that of jet fuel. Thus, the difference between the three fuels is probably not significant.

As a result of the last conclusion, the ratings can be considered from another point of view: summing across fuels and examining the effect of treatment, as shown in Figure 2. The grand mean, of course, remains the same as before but the over-all mean range is higher because there are now three ratings in each set. The phosphate treatment appears to provide more uniform performance because of its lower mean range and because there is only one range which exceeds the 3σ limits calculated for that treatment alone. The two low ratings for coatings 1 and 3 in auto gas again cause the ranges to exceed the limits calculated from the over-all mean range. They also make the mean ranges for wash primer and degreasing considerably greater than that of phosphating. Because of this variability in results, the effectiveness of the metal treatments will be considered later when the ratings for 1964 and 1968 are examined together. The control chart analysis of the two fuels with and without water, corresponding to Table III, will also be made in that section of the report.

The over-all rating of the interior condition of the empty drums was about the same as for the filled drums, except for coating 3 applied to

degreased steel, as shown in Table VIII. Where corrosion did occur, however, it was more general in the empty than in the filled drums to which water had been added. In the latter case usually only the area where water was in contact with the surface was corroded. In empty drums water was able to condense over the entire interior surface so that damage was more widespread.

1968 Interior Results - The ratings assigned to the interior of the drums in 1968 are presented in Table II. From the means of the two fuels, both with and without water, it can be seen that there is little difference between the fuels but that the presence of water greatly affects the results. It is difficult to select the best coatings from Table II because of the effects of the other factors. A statistical analysis is therefore required and, as previously explained, it was made together with the ratings from 1964 to increase the sensitivity of the analysis. Ratings from the automotive gas which did not have water added to it and which was not included in drums examined in 1968 had to be omitted. The results of the analysis of variance of the remaining 96 ratings are presented in Table IX.

As previously found from Table III, the factors of coating, water and coating x water are highly significant. In addition, the fifth main factor, year of examination, is highly significant meaning that for the two years different ratings were obtained from the same combination of the other variables. It would, naturally, be expected that the level of performance would be lowered with an additional four years' exposure. Because there is no interaction of year with the other factors, the ratings for the two examinations tend to fall in the same relative order although reversals probably can be found upon closer examination.

In order to determine whether treatments interacted with the other factors it is again necessary to divide the ratings into two groups according to treatment. The analysis of variance results for the two groups are given in Tables X and XI. They are summarized together with those from Table IX in Table XII for ease of comparison. It is evident that the most important main factors are water, coating and year, with fuel the least important. There is only a significant difference between treatments with phosphate and degreasing. The most significant first order interactions are between water and coatings and between water and treatments. The interaction between coatings and treatments is only significant with the phosphate-degreasing group. Other interactions are either not significant or inconsistently significant at lower confidence levels.

Because there is no significant difference between the two fuels and no significant interactions between them and the other factors, the fuel ratings can be used as the basis for the control chart analysis of the 1964-68 examinations. The results of the mathematical treatment are shown in Table XIII. As there are four remaining factors, the results can be plotted in several ways. Figure 3 shows the control chart analysis with the two main groups being with and without water, since it was found

to be the most significant factor in all the analyses of variance.

Several conclusions can be drawn from Figure 3. The most obvious is the large effect that water has on the performance of the coating systems. The mean rating without water of 8.45 dropped to 5.4 with water. Because of the marked difference between the two groups, the limits for the mean were calculated from the group means, $\bar{\bar{X}}$, rather than the grand mean, $\bar{\bar{\bar{X}}}$. The addition of water did not, however, increase the variability of results as shown by the mean ranges, $\bar{R}$. The sawtooth pattern of the range chart with coatings 1, 5 and 6 indicates that the phosphate results tend to be less variable than those with wash primer.

In Figure 3 there are two ranges that exceed the 99.73% limits calculated from the over-all mean range and two exceeding the 99% limits obtained from the group ranges. Generally the corresponding mean for the pair is depressed, in one case below the 3σ limits for the mean. Hence, the lower rating appears suspect.

If the suspected ratings are replaced by values calculated from the mean range, the substitute means tend to be more reasonably placed in relation to neighboring results. The remaining and corrected mean ratings in the group without water then fall within the 99% limits. Some of the variations between pairs in this group may be due to differences in the tightness of the bung closures. A slightly looser closure could probably allow more water vapor to be sucked into the drum when the temperature dropped. Some drums which did not have water deliberately added to them showed evidence of water on the lower side of the drum. Examples are drums 2 and 83 in Appendix C. The ratings for these two drums are the ones that produced the ranges which exceeded the confidence limits.

In the water-added group, however, there are still pair means exceeding both the upper and lower control limits. The conclusion is that in the presence of water, coating 1 over both pretreatments and coating 2 over degreased steel performed significantly poorer than the other materials. Of greater importance is the conclusion that coating 4 over phosphate and coating 6 over wash primer performed significantly better than the other coatings.

Another way to compare the results is by treatment, as presented in Figure 4. Again the same two ranges exceed the range limits calculated from the over-all mean range, but only one exceeds the 3σ limits of a group range. In this case it is not possible to reject any of the wash primer results on the basis of the group mean range because of the greater variability in results obtained with this treatment. The conclusion that phosphate and degreasing tend to provide more uniform performances substantiates the indication obtained from Figure 3. The greater variation with wash primer may be due to the fact that it must be applied within narrow film thickness limits if it is to perform satisfactorily. It can also be seen from Figure 4 and Table XIII that degreasing was the treatment most affected by the presence of water with a decrease of 4 in the mean rating. Within the

treatment-water subgroups, coating 4 was significantly better and coating 1 significantly poorer over phosphate in the presence of water. Over wash primer with water present, coating 6 was significantly better in 1964 but this could not be proved in 1968 partly owing to a suspect value and also because of the high variability in results with this treatment. Of coatings applied to degreased steel, coating 2 was significantly poorer and coating 4 significantly better when water was added. There is little point in comparing the mean ratings of coatings because of the substantial effect of water on the results and because all coatings were not applied over all the treatments. Figure 4 shows again that only coating 4 over phosphate and coating 6 over wash primer performed well when water was present. Coating 1 over both treatments and 2 over degreased steel are still shown to be the poorest coatings in the presence of water.

With regard to the interior of the empty drums examined in 1968, the ratings for equivalent systems again tend to fall between those for filled drums without water and filled drums with water added. Coating 5 over phosphate performed more poorly, while coating 2 over degreased steel was better than would be expected from the filled drum results.

RESULTS OF EXTERIOR EXAMINATIONS

1964 Exterior Results - The description of the condition of the exterior of the drums is given in Appendix B and the ratings appear in Table XIV. It is evident from the latter that the experimental design is much more balanced than with the interior coatings. There is only one coating which was applied over a different pretreatment and one other which was applied to only one of the treatments. There is also replication as there are five drums to which each coating system was applied. This allows more definite conclusions to be drawn from the experiment.

It is evident from Table XIV that the agreement between ratings of the same system is very good even though they were made in a random order. The highest range in any group of five drums is 2.5 with a mean range of 1.33. For materials subjected to natural exposure for seven years and assessed qualitatively, the consistency of rating is excellent.

The ratings were subjected to an analysis of variance to determine whether the differences between groups are significant in relation to the differences within groups. In this analysis coating 7 had to be disregarded because it was not applied over the same treatments as the other coatings. It was not considered worthwhile to make a separate analysis as there was only one coating in this category. The results of the analysis which are given in Table XV show that the two main factors and their interaction are all very significant. It can also be seen that with a high replication a large number of the degrees of freedom are associated with the residual*.

* The author has calculated that where the number of replicates is r, the d.f. of the residual is $\frac{(r-1)}{r}n$, with n the total number of items. This relationship, which is useful in unbalanced designs, has not been observed in any of the standard textbooks on statistical analysis.

This increases the possibility of establishing the significance of variables being studied provided a sufficient number of d.f. are left for them.

The interpretation of the analysis of variance results is that the differences between the coatings and between the treatments are real and did not occur by chance. The high significance of the interaction means that some coatings performed better over one treatment than over the other, while with other coatings the reverse was true. This is illustrated in Table XV by coatings 1 and 3. Consequently, it is necessary to consider the coating and treatment as a system when selecting the most durable exterior drum finish.

Using this basis, the materials were ranked as shown in Table XVI, which for comparison includes the results from Table IV of the previous report. Because differences between systems with adjacent mean ratings are not significant, they have been given the same rank. A statistical calculation could be made to determine at which level the difference becomes significant. However, because the results were not so treated in the previous report, the calculation is not included here. Table XVI shows that the results from the two examinations do not in general agree upon the order of performance. Coating 1 over phosphate was ranked first in both years, while coating 7-wash primer and coating 5-phosphate placed in about the same rank. Aside from these systems, the rankings are quite different. Calculation of the Rank Correlation Coefficient showed that the two rankings do not correlate. This may have occurred because at the two times of rating different properties, such as chalking or corrosion prevention, may have received emphasis. Another reason may be that with additional exposure the performances tended to become more similar, which could cause reversals in ranking. For example, in 1964 the highest individual drum rating was 8 and the lowest, 4. It should be noted that with the extra four years exposure, the performance level of coating 4 applied directly to phosphated steel without benefit of primer decreased. Its ranking changed from third to seventh. From the descriptions given in Appendix B, it is evident that the phenolated alkyd of coatings 5 and 6 yellowed more than the other finishes. This is expected and, being just an appearance attribute, does not affect the corrosion resistance of the coating.

1968 Exterior Results - The ratings made in 1968 of the exterior condition of the drums were treated similarly to those of 1964. The individual and mean ratings and the ranges are given in Table XVII. The variability of ratings within the groups was somewhat greater in 1968; the mean range of 1.8 is higher than that in Table XIV even though there is one less drum in each group. In spite of the increased variability, an analysis of variance of the ratings showed that the two main factors and their interaction were significant at the same confidence levels as before.

In contrast to the ranges, the grand means are the same for both years. Since some groups have lower means, others must have higher ones. Examples of the latter are coating 1-phosphate and coating 3-degrease. This means that the exterior rating in 1964 must have been more severe because the performance would not be expected to improve with four years of additional exposure. The difference in rating, however, does not affect the ranking as in each year the systems would fall in the same relative order. The rankings for the two years are compared in Table XVIII. When the two rankings were found to correlate with each other at a confidence level of better than 99.5%, they were combined to establish the final rank order presented in the Table.

The ratings from the two examinations were also subjected to the analysis of variance. The same factors were found to be significant at the confidence levels given in Table XV. There was, in addition, an interaction between coatings and years at the 95% confidence level. This is not thought to be too important because the coatings and treatments are being considered as a system in evaluating the results. In agreement with the high rank correlation coefficient, the interaction between coatings, treatments and years was not significant.

The very strong interaction between coatings and treatments is exemplified by coating 1 which over phosphate was the best and over degreased steel the worst of the finishes. Coatings 3 and 5, which employed the same primer, tended to perform better over degreased than over phosphated steel. Evidently the 1-GP-105 primer used in these tests was more tolerant of degreased steel than was the 1-GP-81 primer. Whether this is true in general or only for these particular formulations is not known. It is usually accepted that quick drying primers, like 1-GP-105, require better surface preparation than primers which are slower drying. In this case it is possible that the 1-GP-81 alkyd primer dried as fast as the 1-GP-105 modified alkyd primer. The effectiveness of the primers is demonstrated by the differences in ranking between coating systems 3 and 4 and between systems 5 and 6. In each pair, the even-numbered system had two coats of enamel in place of one coat of primer and one of enamel. Baking the finish did not improve the performance of the alkyd system. Because the same primer was used, the reason for the difference in performance between coating 1 and coating 2 over phosphated steel is not clear. Perhaps the primer tended to become brittle when baked, since it was formulated to air dry.

With regard to exterior appearance, as opposed to corrosion prevention, the filled drums were assessed for chalking in August 1967. The assessments were then rated numerically in a manner similar to that described by Gibbons (1) but using the 0-10 scale. These chalking ratings are given in Table XIX. Chalking of the topcoat should not be affected by the presence or absence of a primer or the type of metal pretreatment.

To ensure that this was indeed the case the ratings were first analyzed statistically. Because of the unbalanced design of the experiment, evident from Table XIX, it was necessary either to treat the primer factor as being nested in the topcoats or to perform analyses of variance on two sections of the experiment. In either case neither treatment nor primer was a significant factor with regard to chalking, as expected. Consequently, the results for each topcoat can be combined to establish the order of chalk resistance. In the nested analysis, topcoats were shown to be significant at the 99.9% level.

When the topcoat means are compared, it can be seen that the order is the same as in the previous report. Only the vinyl finish chalked enough to interfere with its durability. With this coating there was sufficient erosion on the uppermost side of the drum to cause the mottled appearance mentioned in Appendix D. Blisters with some rust also occurred in this area, while with the other finish the lower side of the drum was usually in poorer condition. The phenolated alkyd, which had the second lowest chalking resistance, exhibited mottled areas when not applied over primer. There was not, however, enough erosion to lead to rusting on the body of the drum.

Since, with all finishes except the vinyl, chalking is more related to appearance, it need only be considered as a secondary factor in selecting an exterior drum coating. Fortunately, the air-dried alkyd system which provided the best protection when applied over phosphate treatment had good chalk resistance.

Empty Drum Exteriors - The ratings given the outside of the empty drums in both 1964 and 1968 are summarized in Table XX. The results of the two examinations are considered together because there were only five such drums in 1964 and because the exposure conditions were somewhat different from those of the filled drums. The empty drums were left standing on the ground near the filled drums which were on their sides on racks that kept them off the ground. As time passed grass grew through the gravel and the empty drums tended to sink into the ground, in some cases until the plain end of the drum was in contact with the soil. Hence, the end of these drums was exposed to a more aggressive environment than the filled drums because of the higher moisture content. This is substantiated by the several ratings of 0 appearing in Table XX. These perforations were all in the bottom of the drums and were made from the outside. A rating of 0 was assigned to drums that were perforated because in most cases the contents would have been lost. One or two of the interior linings bridged the holes and appeared to be watertight. Whether they could have resisted the weight of fuel in a filled drum is questionable.

The ratings of the empty drums were converted to rankings and compared with those of the filled drums. It was found that there was no

correlation between the two groups. This is partly due to the fact that there was only one drum for coating 4-phosphate and it had one of the highest ratings. In addition, on the empty drums the phosphate treatment gave better performance than degreasing with coating 3, which is the opposite of results obtained with filled drums. Coating 7 over wash primer was also in much poorer condition on the empty drums. The main conclusion to be drawn from this part of the test is that for long term storage drums should not be in contact with the ground.

CONCLUSIONS

1. Because in many cases there were significant interactions between main factors, over-all conclusions cannot be reached about most of the individual factors. Rather combinations of factors must be considered.

2. Water has a deleterious effect on the performance of some interior drum coatings. Since water vapor may be drawn into a drum, depending upon the tightness of the closures, only those finishes not adversely affected by water should be used for long term storage.

3. The two interior finishing systems which provided good protection whether or not water was present were a phenolic-polyvinyl butyral (coating 4) applied over a phosphate treatment and a commercial epoxy coating (no. 6) applied over wash primer.

4. The epoxy performed better on wash primer than on phosphate in the presence of water. Whether this would be true of coating 4 is unknown because of the possible interaction between coatings and treatments.

5. If wash primer is used as the treatment, close control of application is required in the plant owing to the tendency to variable performance.

6. Coatings applied over degreased steel performed very well in the absence of water but very poorly in its presence. Where absence of water could be ensured, e.g., short term or controlled temperature storage, degreasing should be acceptable with consequent savings in treatment costs.

7. Although the automotive gas left a reddish-brown deposit on the interior of the drums, the performance of the coating systems was not influenced to any extent by the different fuels. Unless hydrocarbon fuels change markedly in the future only one fuel need be used in similar tests. As shown by the Fuels and Lubricants Laboratory Report (2), the fuels were not affected by the coatings.

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(2) Moray, G. and P. L. Strigner. "Long Term Storage of Hydrocarbon Fuels in Coated Drums. Part V: Final Examination of Fuels After Ten Years of Storage," National Research Council, Division of Mechanical Engineering Report MP-52, March 1969.

8. If fuel is removed and the drum left empty for several years, as at a cache, it should not be subsequently refilled under the assumption that it will perform as well as if it had been filled for the same length of time. Empty drums were generally in poorer condition than the corresponding filled drums to which water had not been deliberately added.

9. On the exterior of the drums an air-drying alkyd primer (1-GP-81) and enamel (1-GP-88) performed satisfactorily on phosphated steel with only minor cracking and corrosion. Alkyd enamels, whether air-dried or baked, did not chalk excessively after ten years exposure.

10. If phosphating is considered not feasible or desirable, a modified alkyd primer (1-GP-105) appeared to perform well over simple degreasing. Whether the 1-GP-88 enamel would do as well over this primer was not established but one would not expect a large difference in durability.

11. Drums should be kept off the ground if long term storage in fuel caches is planned. Otherwise the exterior coatings used in this project might not prevent perforation of the ends or hoops in contact with the ground.

12. In studies of this type involving several factors and long exposure periods, greater consideration should be given to experimental design especially with regard to balanced design and replication so that at the end of the tests the validity and usefulness of the results are more definitely established.

ACKNOWLEDGEMENTS

Those responsible for the initial laboratory tests and supervision of drum coating were acknowledged in the preface and reference sections of the previous report. Several technicians of the Building Materials Section have assisted with handling the drums when first placed on the exposure site and during subsequent examinations. Special thanks are due to Mr. R. C. Seeley, who carried out most of the field assessments and diligently looked after the voluminous records of the project. Lectures on statistics by Mr. A. Chamitoff of Bell Canada Ltd. prompted treatment of the results by the control chart technique.

TABLE I

Final Ratings of Interior of Fuel Drums, 1964

Coating Number*	Surface Preparation	No Water			Water Added	
		Fuel			Fuel	
		Aviation Gas	Jet Fuel	Automotive Gas	Aviation Gas	Jet Fuel
1	Wash Primer	10	7.5	2	3	5
	Phosphate	8.5	7.5	7.5	3	0
2	Phosphate	10	9	7	6.5	6.5
	Degrease	10	8.5	6	3	3
3	Phosphate	9.5	9.5	10	6	8.5
	Degrease	10	10	2	6	6.5
4	Phosphate	10	9.5	9.5	9	9.5
	Degrease	10	10	10	7	6.5
5	Wash Primer	10	6	6.5	6.5	5
	Phosphate	8	5	9	6.5	6
6	Wash Primer	10	7	10	10	9
	Phosphate	9.5	9.5	9.5	6.5	7

* 1. Phenolic-epoxy modified with polyvinyl butyral.
2. Amine-cured epoxy.
3. Phenolic modified with epoxy and polyvinyl butyral.
4. Phenolic modified with polyvinyl butyral.
5. Vinyl chloride-vinyl acetate copolymer.
6. Commercial epoxy coating.

TABLE II

Final Ratings of Interior of Fuel Drums, 1968

Coating Number	Surface Preparation	No Water		Water Added		Empty Drum	
		Aviation Gas	Jet Fuel	Aviation Gas	Jet Fuel		
1	Wash Primer	3	8	4	2	7	7
	Phosphate	9	9	2	2	5	8
2	Phosphate	8	9.5	6	6	9 7	7
	Degrease	9.5	5	1	2	9.5	9.5
3	Phosphate	9.5	7	4	6	9	5
	Degrease	10	9.5	5	4	6	10
4	Phosphate	8	8	8	8	9	
	Degrease	7	7	6	8	8	6
5	Wash Primer	5	8	3	5	5	7
	Phosphate	9	9	1	6	2	2
6	Wash Primer	8	6	9	5	9	8
	Phosphate	9	10	5	5	9	8
Mean Rating		7.9	8.0	4.5	4.9	7.2	

TABLE III

Analysis of Variance of 1964 Results

Automotive Gas excluded

Treatments nested in Coatings

Factor	Degrees of Freedom	Mean Square	Variance Ratio	Significance Level
Total	47			
Coating	5	13.55	8.40	99.9%
Treatment	4	4.25	2.64	N.S.*
Fuel	1	6.021	3.73	N.S.
Water	1	99.188	61.51	>99.9%
C x F (Coating and Fuel)	5	2.021	1.25	N.S.
C x W (Coating and Water)	5	7.313	4.53	99 %
F x W (Fuel and Water)	1	5.333	3.31	N.S.
C x F x W	5	0.258	0.16	N.S.
Residual**	20***	1.613	-	-
48 ratings				

* N.S. = Not Significant

** The term "residual" refers to the residual variability found in any process or experiment providing the method of measurement is sensitive enough to detect it. Any variability greater than the natural or inherent variability is assignable to a cause and the aim of experiments is to find which factors affect the results.

*** The degrees of freedom (d.f.) for the residual are high, which gives a better chance to show that experimental factors are significant, because the treatment interactions with the other factors cannot be separated with this design.

TABLE IV

Analysis of Variance of 1964 Results
Phosphate and Wash Primer Treatments

Factor	d.f.	Mean Square	Variance Ratio	Significance Level
Total	23			
Coating	2	18.510	12.78	92.5%
Treatment	1	6.0	4.14	N.S.
Fuel	1	12.042	8.31	N.S.
Water	1	40.042	27.64	95 %
C x T (Coating and Treatment)	2	0.656	0.453	N.S.
C x F	2	1.073	0.74	N.S.
C x W	2	13.948	9.63	90 %
T x F	1	0.375	0.259	N.S.
T x W	1	2.042	1.41	N.S.
F x W	1	4.167	2.88	N.S.
C x T x F	2	2.094	1.45	N.S.
C x T x W	2	4.259	2.94	N.S.
C x F x W	2	0.260	0.18	N.S.
T x F x W	1	2.667	1.84	N.S.
Residual 24 ratings	2	1.449	-	-

Even a variance ratio of 8.3 was not significant because of the few d.f. associated with the residual when there is no replication. Interactions with a variance ratio less than 1 were added to the residual. Second order interactions which were still not significant were next added to the residual to ensure that the remaining variance ratios were not artificially inflated.

Coating	2	18.510	17.06	99.9%
Treatment	1	6.0	5.53	95 %
Fuel	1	12.042	11.10	99 %
Water	1	40.042	36.90	99.9%
C x W	2	13.948	12.85	99.9%
T x W	1	2.042	1.88	N.S.
F x W	1	4.167	3.84	N.S.
C x T x W	2	4.259	3.92	N.S.
Residual	13	1.085	-	-

TABLE V

Analysis of Variance of 1964 Results
Phosphate and Degreasing Treatments

Factor	d.f.	Mean Square	Variance Ratio	Significance Level
Total	23			
Coating	2	7.198	32.90	95 %
Treatment	1	7.042	32.19	95 %
Fuel	1	Ø	Ø	N.S.
Water	1	60.167	275.1	99 %
C x T	2	1.323	6.05	N.S.
C x F	2	0.969	4.43	N.S.
C x W	2	3.823	17.48	92.5%
T x F	1	0.375	1.71	N.S.
T x W	1	9.375	42.86	97.5%
F x W	1	1.5	6.86	N.S.
C x T x F	2	0.094	0.43	N.S.
C x T x W	2	0.406	1.86	N.S.
C X F x W	2	0.219	1.00	N.S.
T x F x W	1	0.375	1.71	N.S.
Residual	2	0.219	-	-
24 ratings				

In spite of the low mean square associated with the residual, only a few factors could be proved significant because of the few d.f. of the residual. Interactions with a mean square less than 1 were added to the residual:

Coating	2	7.198	18.93	99.9%
Treatment	1	7.042	18.52	99.9%
Fuel	1	Ø	Ø	N.S.
Water	1	60.167	158.2	>99.9%
C x T	2	1.323	3.48	N.S.
C x W	2	3.823	10.05	99 %
T x W	1	9.375	24.66	99.9%
F x W	1	1.5	3.95	N.S.
Residual	12	0.380	-	-

TABLE VI

Analysis of Variance of 1964 Results

Three Fuels Without Water

Factor	d.f.	Mean Square	Variance Ratio	Significance Level
Total	35			
Coating	5	6.324	2.04	N.S.
Treatment	3	3.931	1.27	N.S.
Fuel	2	14.924	4.81	95%
C x F	10	3.774	1.22	N.S.
Residual	15	3.	-	-
36 ratings				

TABLE VII

Control Chart Analysis of 1964 Results

Three Fuels Without Water

Fuel	Mean	Mean Range
Aviation Gas	9.63	0.75
Jet Fuel	8.25	0.83
Automotive	7.42	3.0
All three	8.43	1.53

TABLE VIII

Interior Rating of Empty vs Filled Drums

Drum Number	Coating Number	Surface Preparation	Empty Rating	Mean Filled Rating	
				No Water	Water Added
21	1	Wash Primer	9	6.5	4
90	2	Degreasing	9	8.67	6.5
111	3	Phosphate	7	9.67	7.25
122	3	Degreasing	3	7.33	6.25
258	6	Wash Primer	9.5	9.0	9.5

TABLE IX

Analysis of Variance of 1964-68 Results

Automotive Gas excluded

Treatments nested in Coatings

Factor	Degrees of Freedom	Mean Square	Variance Ratio	Significance Level
Total	95			
Coating	5	21.079	8.34	99.9%
Treatment	5	5.825	2.31	N.S.
Fuel	1	1.26	0.50	N.S.
Water	1	225.094	89.10	>99.9%
Year	1	32.667	12.93	99.9%
C x F (Coating and Fuel)	5	0.985	0.39	N.S.
C x W	5	10.944	4.33	99 %
C x Y	5	0.404	0.16	N.S.
F x W	1	4.167	1.65	N.S.
F x Y	1	5.510	2.18	N.S.
W x Y	1	0.844	0.33	N.S.
C x F x W	5	1.654	0.65	N.S.
C x F x Y	5	4.535	1.80	N.S.
C x W x Y	5	2.919	1.16	N.S.
F x W x Y	1	1.500	0.59	N.S.
C x F x W x Y	5	1.288	0.51	N.S.
Residual	43	2.526	-	-
96 ratings				

TABLE X

Analysis of Variance of 1964-68 Results

Phosphate and Wash Primer Treatments

Factor	d.f.	Mean Square	Variance Ratio	Significance Level
Total	47			
Coating	2	28.193	4.19	N.S.
Treatment	1	0.083	0.01	N.S.
Fuel	1	1.688	0.25	N.S.
Water	1	117.188	17.43	94%*
Year	1	12.00	1.78	N.S.
C x T	2	0.349	0.05	N.S.
C x F	2	1.516	0.23	N.S.
C x W	2	13.891	2.07	N.S.
C x Y	2	0.609	0.09	N.S.
T x F	1	1.021	0.15	N.S.
T x W	1	20.021	2.98	N.S.
T x Y	1	10.083	1.50	N.S.
F x W	1	0.333	0.05	N.S.
F x Y	1	13.021	1.94	N.S.
W x Y	1	3.521	0.52	N.S.
C x T x W	2	3.505	0.52	N.S.
C x T x F	2	5.068	0.75	N.S.
C x T x Y	2	0.849	0.13	N.S.
C x F x W	2	3.005	0.45	N.S.
C x F x Y	2	6.599	0.98	N.S.
C x W x Y	2	3.349	0.50	N.S.
T x F x W	1	0.75	0.11	N.S.
T x F x Y	1	0.021	0.003	N.S.
T x W x Y	1	6.021	0.90	N.S.
F x W x Y	1	5.333	0.79	N.S.
C x T x F x W	2	0.766	0.11	N.S.
C x T x F x Y	2	0.318	0.04	N.S.
C x T x W x Y	2	1.130	0.17	N.S.
C x F x W x Y	2	1.130	0.17	N.S.
T x F x W x Y	1	0.583	0.09	N.S.
Residual 48 ratings	2	6.724	-	-

* Estimated

TABLE X (Cont'd)

Nothing could be proved significant except water at the 94% level because of the few d.f. associated with the residual. Second order and higher interactions with a mean square less than 1 were added to the residual as in Table V.

Factor	d.f.	Mean Square	Variance Ratio	Significance Level
Coating	2	28.193	16.61	99.9%
Treatment	1	0.083	0.05	N.S.
Fuel	1	1.688	0.99	N.S.
Water	1	117.188	69.06	>99.9%
Year	1	12.00	7.07	97.5%
C x T	2	0.349	0.21	N.S.
C x F	2	1.516	0.89	N.S.
C x W	2	13.891	8.19	99 %
C x Y	2	0.609	0.36	N.S.
T x F	1	1.021	0.60	N.S.
T x W	1	20.021	11.80	99 %
T x Y	1	10.083	5.94	95 %
F x W	1	0.333	0.20	N.S.
F x Y	1	13.021	7.67	97.5%
W x Y	1	3.521	2.07	N.S.
C x T x W	2	3.521	2.07	N.S.
C x T x F	2	5.068	2.99	N.S.
C x F x W	2	3.005	1.77	N.S.
C x F x Y	2	6.599	3.89	N.S.
C x W x Y	2	3.349	1.97	N.S.
T x W x Y	1	6.021	3.55	N.S.
F x W x Y	1	5.333	3.14	N.S.
C x T x W x Y	2	1.130	0.67	N.S.
C x F x W x Y	2	1.130	0.67	N.S.
Residual	11	1.697	-	-

TABLE XI

Analysis of Variance of 1964-68 Results

Phosphate and Degreasing Treatments

Factor	d.f.	Mean Square	Variance Ratio	Significance Level
Total	47			
Coating	2	12.505	8.48	N.S.
Treatment	1	15.188	10.30	90 %
Fuel	1	0.083	0.06	N.S.
Water	1	108.0	73.27	97.5%
Year	1	21.333	14.47	92.5%*
C x T	2	6.578	4.46	N.S.
C x F	2	0.693	0.47	N.S.
C x W	2	13.422	9.11	N.S.
C x Y	2	0.068	0.05	N.S.
T x F	1	1.021	0.69	N.S.
T x W	1	13.021	8.83	N.S.
T x Y	1	0.021	0.01	N.S.
F x W	1	5.333	3.62	N.S.
F x Y	1	0.083	0.06	N.S.
W x Y	1	0.333	0.23	N.S.
C x T x F	2	0.786	0.53	N.S.
C x T x W	2	0.849	0.58	N.S.
C x T x Y	2	0.911	0.62	N.S.
C x F x W	2	0.380	0.26	N.S.
C x F x Y	2	0.943	0.64	N.S.
C x W x Y	2	2.443	1.66	N.S.
T x F x W	1	0.021	0.01	N.S.
T x F x Y	1	0.021	0.01	N.S.
T x W x Y	1	0.521	0.35	N.S.
F x W x Y	1	0.333	0.23	N.S.
C x T x F x W	2	3.286	2.23	N.S.
C x T x F x Y	2	0.849	0.58	N.S.
C x T x W x Y	2	0.724	0.49	N.S.
C x F x W x Y	2	0.005	0.004	N.S.
T x F x W x Y	1	1.021	0.69	N.S.
Residual 48 ratings	2	1.474	-	-

* Estimated

TABLE XI (Cont'd)

As before it was difficult to establish significance so interactions (except first order) with a mean square less than 1 were added to the residual as shown below:

Factor	d.f.	Mean Square	Variance Ratio	Significance Level
Coating	2	12.505	18.25	99.9%
Treatment	1	15.188	22.16	99.9%
Fuel	1	0.083	0.12	N.S.
Water	1	108.0	157.6	>99.9%
Year	1	21.333	31.13	99.9%
C x T	2	6.578	9.60	99.9%
C x F	2	0.693	1.01	N.S.
C x W	2	13.422	19.59	99.9%
C x Y	2	0.068	0.10	N.S.
T x F	1	1.021	1.49	N.S.
T x W	1	13.021	19.00	99.9%
T x Y	1	0.021	0.03	N.S.
F x W	1	5.333	7.78	97.5%
F x Y	1	0.083	0.12	N.S.
W x Y	1	0.333	0.49	N.S.
C x W x Y	2	2.443	3.56	95 %
C x T x F x W	2	3.286	4.80	95 %
Residual	23	0.685	-	-

TABLE XII

Summary of Analysis of 1964-68 Ratings

Insignificant Higher Order Interactions omitted

Factor	Phosphate and Wash Primer	Phosphate and Degreasing	All Three Treatments
Coating	99.9%	99.9%	99.9%
Treatment	N.S.	99.9	N.S.
Fuel	N.S.	N.S.	N.S.
Water	>99.9	>99.9	>99.9
Year	97.5	99.9	99.9
Coating & Treatment	N.S.	99.9	-
Coating & Fuel	N.S.	N.S.	N.S.
Coating & Water	99.9	99.9	99
Coating & Year	N.S.	N.S.	N.S.
Treatment & Fuel	N.S.	N.S.	-
Treatment & Water	99	99.9	-
Treatment & Year	95	N.S.	-
Fuel & Water	N.S.	97.5	N.S.
Fuel & Year	97.5	N.S.	N.S.
Water & Year	N.S.	N.S.	N.S.
C x W x Y	N.S.	95	N.S.
C x T x F x W	N.S.	95	-

TABLE XIII

Control Chart Analysis of 1964-68 Results

Treatment	Parameter	No Water	Water Added	Both With and Without Water
Phosphate	Mean	8.77	5.58	7.18
	Range	0.88	1.17	1.02
Wash Primer	Mean	7.34	5.54	6.46
	Range	3.25	2.08	2.67
Degreasing	Mean	8.88	4.83	6.85
	Range	1.08	0.83	0.96
All Treatments	Mean	8.45	5.39	6.92
	Range	1.52	1.31	1.42

TABLE XIV

Rating of Exterior Drum Coatings in 1964

Coating No.*	Treatment	Ratings	Mean	Range
1	Degreasing	4 , 4 , 4 , 5 , 4	4.2	1
	Phosphate	7 , 7.5, 7.5, 7.5, 6	7.1	1.5
2	Degreasing	5 , 6 , 5 , 5 , 4	5.0	2
	Phosphate	6 , 6.5, 6.5, 6.5, 6	6.3	0.5
3	Degreasing	6.5, 7 , 6.5, 7.5, 6	6.7	1.5
	Phosphate	6 , 5 , 7 , 7 , 6	6.2	2
4	Degreasing	6 , 6 , 6 , 6 , 6	6.0	0
	Phosphate	6 , 6 , 6.5, 6.5, 6	6.2	0.5
5	Degreasing	6.5, 7 , 7 , 8 , 6.5	7.0	1.5
	Phosphate	6.5, 7 , 7.5, 6 , 6.5	6.7	1.5
6	Phosphate	6 , 6.5, 6.5, 5 , 4	5.6	2.5
7	Wash Primer	6.5, 6.5, 6.5, 7.5, 6	6.6	1.5
Mean			6.13	1.33

* 1. Air-dried alkyd primer and enamel.
2. Baked alkyd primer and enamel.
3. Modified alkyd primer and styrenated alkyd enamel.
4. Two coats styrenated alkyd enamel.
5. Modified alkyd primer and phenolated alkyd enamel.
6. Two coats phenolated alkyd enamel.
7. Vinyl wash primer and two coats vinyl lacquer.

TABLE XV

Analysis of Variance of 1964 Exterior Results

Coating 7 excluded

Factor	d.f.	Mean Square	Variance Ratio	Significance Level
Coating	4	2.429	6.40	99.9%
Treatment	1	4.430	11.67	99.5%
Coating x Treatment	4	5.442	14.34	>99.9%
Residual	44	0.3795	-	-
Total 55 ratings	54			

TABLE XVI

Ranking of Exterior Drum Coatings

Rank*	1964 Results	1959-63 Results
1	(Coating 1 - Phosphate (Coating 5 - Degrease	Coating 1 - Phosphate
2		Coating 3 - Phosphate
3		Coating 4 - Phosphate
4	(Coating 3 - Degrease (Coating 5 - Phosphate (Coating 7 - Wash Primer	Coating 7 - Wash Primer
5		Coating 5 - Phosphate
6		(Coating 2 - Degrease
7	(Coating 2 - Phosphate (Coating 3 - Phosphate (Coating 4 - Phosphate	(Coating 1 - Degrease
8		Coating 5 - Degrease
9	Coating 4 - Degrease	Coating 2 - Phosphate
10	Coating 6 - Phosphate	Coating 3 - Degrease
11	Coating 2 - Degrease	Coating 6 - Phosphate
12	Coating 1 - Degrease	Coating 4 - Degrease

* Where two items are ranked the same, each is assigned the mean of the consecutive rank numbers.

R = 0.353

TABLE XVII

Rating of Exterior Drum Coatings in 1968

Coating No.	Treatment	Ratings	Mean	Range
1	Degreasing	4, 3, 4, 4	3.75	1
	Phosphate	8, 8, 8, 8.5	8.13	0.5
2	Degreasing	5, 6, 6, 6	5.75	1
	Phosphate	5, 8, 6, 7	6.5	3
3	Degreasing	8, 8, 8, 8	8	0
	Phosphate	6, 4, 8, 9	6.75	5
4	Degreasing	4, 3, 6, 4	4.25	3
	Phosphate	7, 6, 5, 6	6	2
5	Degreasing	8.5, 6, 8.5, 6	7.25	2.5
	Phosphate	7, 7, 7, 8	7.25	1
6	Phosphate	5, 5, 7, 5	5.5	2
7	Wash Primer	6, 5, 6, 5	5.5	1
Mean			6.22	1.83

TABLE XVIII

Ranking of Exterior Drum Coatings

Coating No.	Treatment	Rank		
		1968	1964	Combined
1	Degreasing	12	12	12
	Phosphate	1.5	1.5	1
2	Degreasing	8	11	9
	Phosphate	6	7	6
3	Degreasing	1.5	4	3
	Phosphate	5	7	5
4	Degreasing	11	9	11
	Phosphate	7	7	8
5	Degreasing	3.5	1.5	2
	Phosphate	3.5	4	4
6	Phosphate	9.5	10	10
7	Wash Primer	9.5	4	7

TABLE XIX

Chalk Resistance of Exterior Drum Coatings

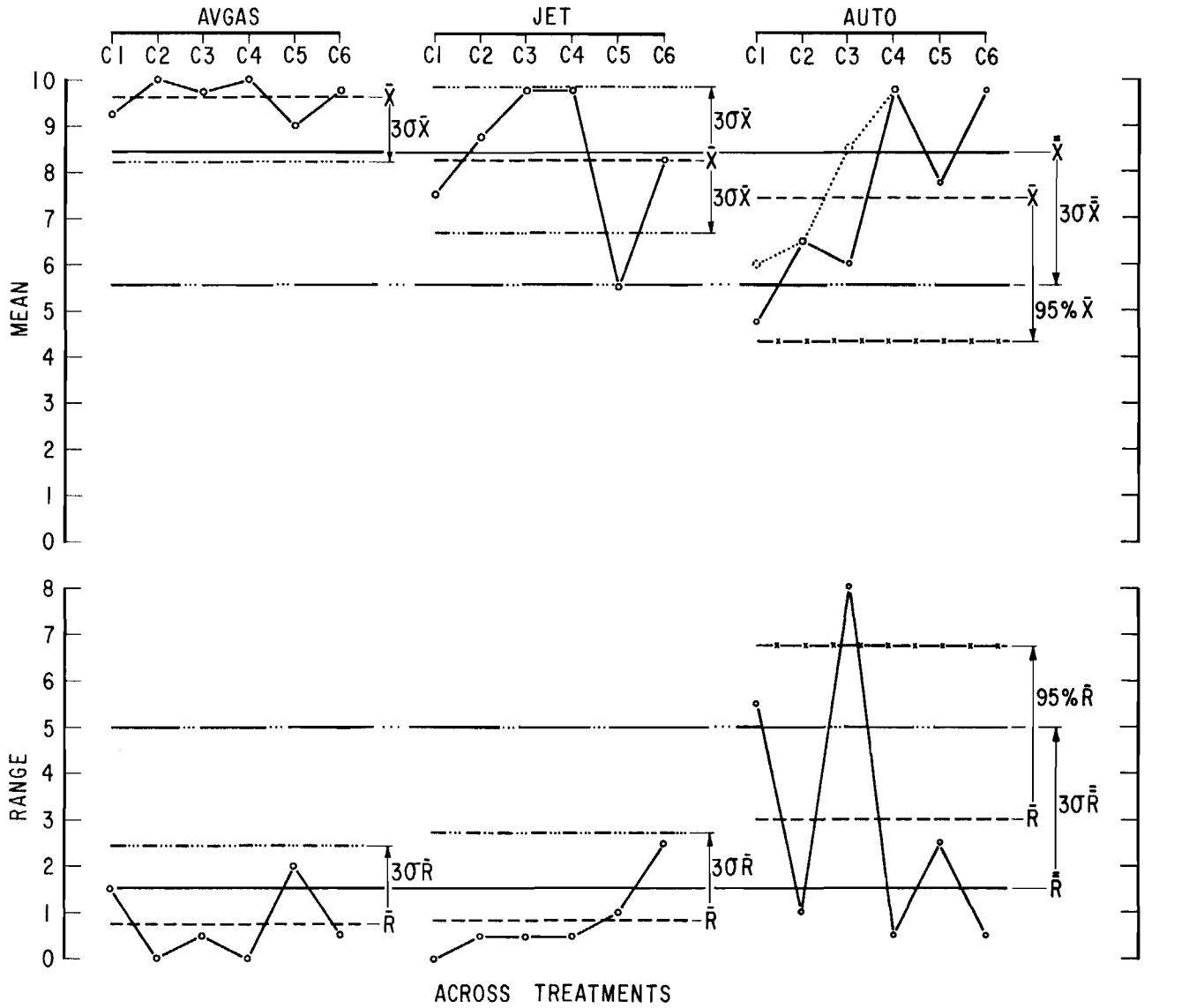
Topcoat	With Primer		Without Primer			Mean Rating
	Degrease	Phos-phate	Degrease	Phos-phate	Wash Primer	
Air Dried	3	3				
Alkyd	3	3				
Enamel	8	3				
	3	4				
	4.25	3.25				3.75
Baked	3	3				
Alkyd	5	3				
Enamel	8	6				
	3	3				
	4.75	3.75				4.25
Styren-ated	1	2	3	3		
Alkyd	2	1	2	2		
Enamel	2	2	1	3		
	2	2	2	2		
	1.75	1.75	2.0	2.5		2.0
Phenolated	3	2		2		
Alkyd	1	1		1		
Enamel	1	2		1		
	2	2		2		
	1.75	1.75		1.5		1.67
Vinyl					1	
					1	
					1	
					1	
					1	1

10 = no chalking
8 = trace chalking
6 = slight chalking
5 = slight-moderate
4 = moderate
3 = marked
2 = very marked
1 = very severe
0 = completely eroded

TABLE XX

Rating of Exterior Coatings on Empty Drums

Coating No.	Treatment	Rating			
		1964	1968		
1	Degrease	0	1	1	
	Phosphate	-	4	5	
2	Degrease	1	0	0	
	Phosphate	-	4	3	0
3	Degrease	5	3	5	
	Phosphate	7.5	5	6	
4	Degrease	6	3	3	
	Phosphate	-	6		
5	Degrease	-	5	4	
	Phosphate	-	4	2	
6	Phosphate	-	3	3	
7	Wash Primer	-	2	2	

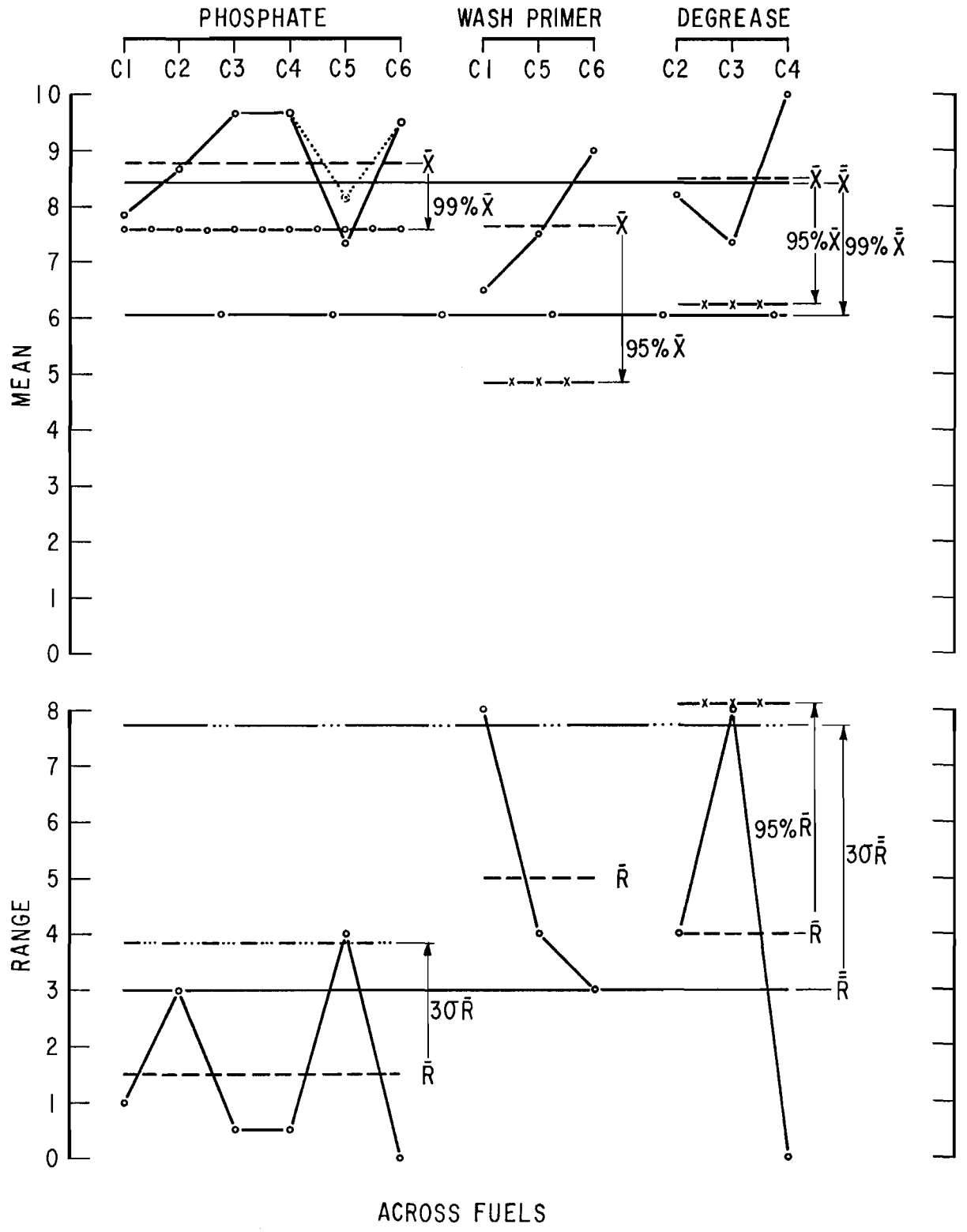


LEGEND:

$\bar{\bar{X}}$ = GRAND MEAN	3σ GRAND MEAN LIMITS	95 % GRAND MEAN LIMITS
$\bar{X}$ = GROUP MEAN	3σ GROUP MEAN LIMITS	95 % GROUP MEAN LIMITS
$\bar{\bar{R}}$ = GRAND MEAN RANGE	99 % GRAND MEAN LIMITS	RECALCULATED VALUES
$\bar{R}$ = GROUP MEAN RANGE	99 % GROUP MEAN LIMITS	

FIGURE 1 1964 RESULTS - THREE FUELS WITHOUT WATER

BR. 4827-1

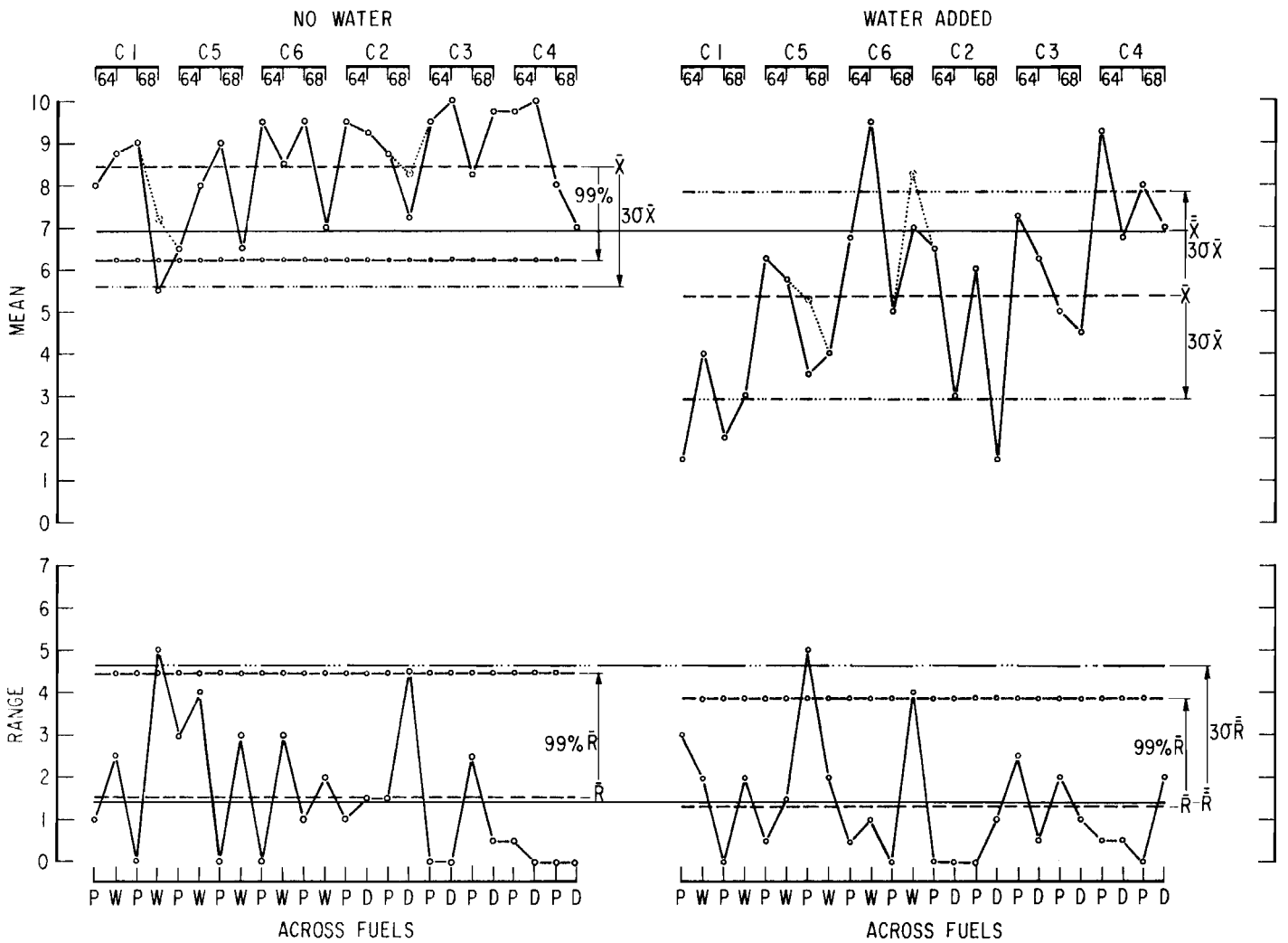


LEGEND:

$\bar{\bar{X}}$ = GRAND MEAN	3σ GRAND MEAN LIMITS	95% GRAND MEAN LIMIT	
$\bar{X}$ = GROUP MEAN	3σ GROUP MEAN LIMITS	95% GROUP MEAN LIMIT	
$\bar{\bar{R}}$ = GRAND MEAN RANGE	99% GRAND MEAN LIMITS	RECALCULATED VALUES	
$\bar{R}$ = GROUP MEAN RANGE	99% GROUP MEAN LIMITS		

FIGURE 2 1964 RESULTS - THREE FUELS WITHOUT WATER

BR 4827-2



LEGEND:

$\bar{\bar{X}}$ = GRAND MEAN — 3σ GRAND MEAN LIMITS — 95% GRAND MEAN LIMITS

$\bar{X}$ = GROUP MEAN ----- 3σ GROUP MEAN LIMITS — 95% GROUP MEAN LIMITS

$\bar{\bar{R}}$ = GRAND MEAN RANGE — 99% GRAND MEAN LIMITS — RECALCULATED VALUES

$\bar{R}$ = GROUP MEAN RANGE ----- 99% GROUP MEAN LIMITS

P = PHOSPHATE, W = WASH PRIMER, D = DEGREASING

FIGURE 3 1964-68 RESULTS - TWO FUELS

SK 4827-3

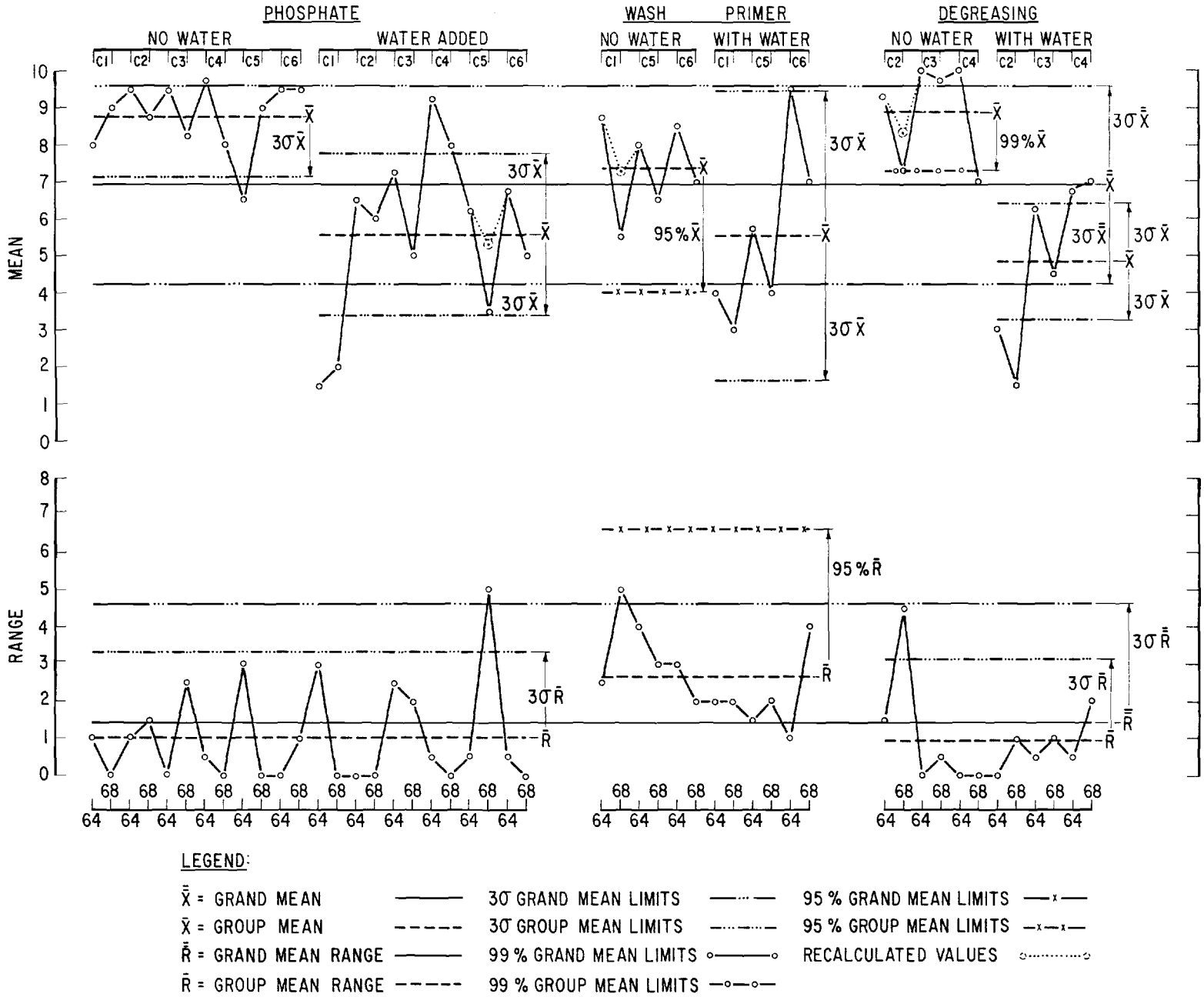


FIGURE 4 1964-68 RESULTS - TWO FUELS

SR 4827-4

APPENDIX A

Condition of Interiors of Fuel Drums Removed in November 1964

Drum No.	Coating System	Contents	Description	Rating
3	W1	Avgas	Few dents on hoops. Film in perfect condition.	10
7	W1	Avgas + Water	Several large rust spots and blisters and strips of whitening where water lay. Strip of small blisters in air space. Filiform corrosion near air space. Blisters on end of drum.	3
15	W1	Jet Fuel	Small strip of flat blisters along bottom. Small area of rusting and blisters in air space. Medium blisters on end.	7-1/2
17	W1	Jet Fuel + Water	Marked whitening and some mottled blisters where water lay. Moderate whitening and mottled blisters in air space. Filiform corrosion 20% of area.	5
18	W1	MT Gas	Heavy red deposit from fuel except in air space. Whitening and small blisters in bottom. Severe rusting in first ring and deteriorated strip in air space.	2
21	W1	None (Stood on end)	Seven holes in end of drum, one through coating, rusted from outside (not fault of interior coating). Few white spots and slight rust at seam.	9*
30	P1	Avgas	Few pimples in top ring near end completely around drum. Few black deposits from fuel in bottom.	8-1/2
34	P1	Avgas + Water	Severe rusting and strip of whitening where water lay. 3 in. strip of rust blisters in air space. Fine white blisters near air space. Flat pimples over bottom half of drum.	3
37	P1	Jet Fuel	Moderate fuel deposit except in air space. Flat blisters over moderate area. Few black deposits from fuel in bottom.	7-1/2

* Perforation from exterior.

Drum No.	Coating System	Contents	Description	Rating
40	P1	Jet Fuel + Water	Wide strip of bare metal and rust patches where water lay. Small hole in each hoop through the steel. Severe rust blisters and strip of whitening in air space.	0
45	P1	MT Gas	Reddish brown general deposit and few black deposits in bottom from fuel. Several rust blisters in hoops and whitening in rings in air space.	7-1/2
51	P2	Avgas	Excellent condition	10
53	P2	Avgas + Water	Moderate whitening and blisters where water lay. One small patch of rusting in air space. Few rust spots along seam.	6-1/2
57	P2	Jet Fuel	Whitening around seam.	9
59	P2	Jet Fuel + Water	Whitening and blistering where water lay, especially in hoops. One small patch of rusting and some whitening in air space.	6-1/2
62	P2	MT Gas	Moderate brown deposit from fuel. Small strip of whitening with blisters in hoops at bottom of drum. Slight rusting at seam.	7
76	G2	Avgas	Film appears rough but in excellent condition. Several black deposits from fuel.	10
79	G2	Avgas + Water	Severe small blisters and rusting where water lay. Large rust blisters in air space. Deposit from fuel.	3
82	G2	Jet Fuel	One small patch blisters with some rust at bottom. Faint white spots in air space. Moderate deposit from fuel.	8-1/2
86	G2	Jet Fuel + Water	Strip of severe small rust blisters and starting to peel where water lay. Small patch of rust blisters and black area in air space. Slight rust on seam. Moderate deposit from fuel.	3

Drum No.	Coating System	Contents	Description	Rating
88	G2	MT Gas	Marked rust blisters and strip of whitening in air space. Brown deposit from fuel elsewhere.	6
90	G2	None	Few small rust spots scattered over drum. Slight rust on seam.	9
99	P3	Avgas	White mark on hoop from dropping drum. End of drum yellowish.	9-1/2
102	P3	Avgas + Water	Marked yellow-white strip where water lay. Whitening with some rust blisters in air space. Many application sags.	6
105	P3	Jet Fuel	Slight bloom on surface. End of drum yellowish.	9-1/2
108	P3	Jet Fuel + Water	Slight whitening and fuel deposit where water lay. Whitening in air space.	8-1/2
110	P3	MT Gas	Heavy deposit from fuel except in air space.	10
111	P3	None	20% rust blistering in end of drum from standing on end.	7
122	G3	None	Small rust spots all over drum, rust along seam. Large blisters in end from one in. water collected.	3
125	G3	Avgas	Sharp dent in first hoop from dropping drum. Film appears slightly rough but in excellent condition.	10
128	G3	Avgas + Water	Marked whitening of coating and rust blisters in hoops where water lay. Whitening with some rust blisters in air space.	6
132	G3	Jet Fuel	Film appears slightly rough but in excellent condition.	10
134	G3	Jet Fuel + Water	Marked whitening and fine corrosion where water lay. Moderate whitening and several rust blisters in air space. One rust area where drum dented from dropping. Brown fuel stain where water lay.	6-1/2

Drum No.	Coating System	Contents	Description	Rating
142	G3	MT Gas	Severe rusting with peeling in air space. Moderate whitening at bottom and heavy fuel deposit except in air space.	2
150	P4	Avgas	Excellent condition	10
154	P4	Avgas + Water	One fairly white area where water lay. Slight white strip in air space. Slight rust on seam.	9
156	P4	Jet Fuel	Few small red-brown specks in front hoop. Film yellowish.	9-1/2
160	P4	Jet Fuel + Water	Film lifted on dent from dropping drum. Slight rusting on seam.	9-1/2
162	P4	MT Gas	Film lifted on dents from dropping drum. Deposit from fuel except in air space.	9-1/2
170	G4	Avgas	Film appears rough but in excellent condition.	10
173	G4	Avgas + Water	Slight corrosion strip where water lay, especially in hoops. Film appears rough but in excellent condition. Stain from fuel except in air space.	7
177	G4	Jet Fuel	Film appears rough but in excellent condition. Slight deposit from fuel.	10
180	G4	Jet Fuel + Water	Yellowing and fine corrosion where water lay. Slight whitening in air space. Film appears rough elsewhere.	6-1/2
182	G4	MT Gas	Film appears rough but in excellent condition. Few black deposits in bottom and heavy overall fuel deposit except in air space.	10
195	W5	Avgas	Film in excellent condition.	10
198	W5	Avgas + Water	Small area of rust blisters where water lay. Small blisters and few rust spots in air space. Beginning of filiform corrosion on side near seam.	6-1/2

Drum No.	Coating System	Contents	Description	Rating
200	W5	Jet Fuel	Strip of blisters in bottom with rust in hoops. Few rust blisters and beginning of fine corrosion in air space. Few black deposits or blotches around drum.	6
204	W5	Jet Fuel + Water	White blisters and rusting in hoops where water lay. Some blisters and beginning of fine corrosion in air space. Filiform corrosion in one area. Black stains in lower half of drum.	5
206	W5	MT Gas	Slight marks in hoops at bottom. Filiform corrosion in lower half. Beginning of fine corrosion in air space. Small area of rust spots with peeling one end of drum. Heavy fuel deposit.	6-1/2
223	P5	Avgas	Very fine blister or overspray around first ring. Slight bloom on coating. Slight rust on seam.	8
225	P5	Avgas + Water	Slight white strip with microblisters in air space. Filiform corrosion along seam. Loss of adhesion over dents from dropping drum.	6-1/2
231	P5	MT Gas	Loss of adhesion over dents from dropping drum. Application sags. Heavy fuel deposit except in air space.	9
234	P5	Jet Fuel	Severe rusting at small areas in bottom especially in hoops. Fine corrosion in air space. Lifting with fresh rust under dents from dropping. Application sags.	5
237	P5	Jet Fuel + Water	Slight white strip and one area of rust in hoop where water lay. Slight overall corrosion in air space. Loss of adhesion over dent from dropping. Some application sags.	6
244	W6	Avgas	Film in excellent condition.	10
248	W6	Avgas + Water	Very slight whitish strip where water lay but in excellent condition.	10

Drum No.	Coating System	Contents	Description	Rating
251	W6	Avgas + Water	Very slight whitish strip where water lay but in excellent condition.	10
254	W6	Jet Fuel + Water	Slight whitening where water lay. Slight whitening and two rust blisters in air space.	9
256	W6	MT Gas	Heavy orange peel on end. Heavy fuel deposit except in air space.	10
258	W6	None	Slight rusting along seam. Sides and end excellent.	9-1/2
271	P6	Avgas	Several dents from dropping but loss of adhesion over only one. Film in excellent condition.	9-1/2
273	P6	Avgas + Water	Row of 1/4 in. blisters along scratch mark and one patch of blisters in air space. Loss of adhesion over dents from dropping.	6-1/2
277	P6	Jet Fuel	Two dents from dropping but loss of adhesion over only one. Very slight whitening in bottom.	9-1/2
279	P6	Jet Fuel + Water	Slight whitening where water lay. Slight whitening and few severe rust spots in air space. Loss of adhesion over two dents from dropping.	7
282	P6	MT Gas	Loss of adhesion over three dents from dropping. Heavy fuel deposit exception air space. Film in excellent condition.	9-1/2

APPENDIX B

Condition of Exteriors of Fuel Drums in 1964

Drum No.	Coating System	Group No.	Description	Rating
3	1Degrease	1	Marked peeling and rusting at chime and bungs on bung end. Not quite as bad on plain end. Small rust blisters along seam. Marked wear with moderate corrosion on lower rim. Sl-mod. wear with sl-mod. corrosion on upper rim. Paint flaked off hoops with moderate corrosion. Cracks with lifting on body from dropping drum. Moderate dirt on bottom* with 2 sq.in. rust blisters at one end.	4
7	1D	1	Severe peeling and rusting at bung end. Moderate cracking with rusting at other end. Rims badly corroded. Slight blistering along seam. Paint removed in spots along hoops with 50% rust spots. Dirt on bottom with 1 sq.in. rusting.	4
15	1D	1	Severe flaking at chime with rust; one half at bung end, 10 in. at other. Few small areas rust, some areas of fine cracks with rust on plain end and at bungs. Moderate wear with corrosion on lower rim. Sl. wear with sl. corrosion on upper rim. Few blisters along seams. Paint flaked off hoops with some corrosion. Moderate dirt with 1/2 sq.in. rust.	4
17	1D	1	Several areas of peeling and rusting at chimes - worse on bung end. Peeling with rust at small bung. Moderate wear with rust on rims. Trace blistering along seam. Paint removed at many small spots on hoops and body with marked rusting. Sl-mod. dirt on bottom with 1/2 sq.in. rust.	5

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* In Appendix B, bottom refers to the lowermost portion of the side of the drum facing the ground. Water from rain and condensation ran around the drum and tended to collect in a strip a few inches in width and the length of the drum. There was no equivalent position on the empty drums which stood on end.

Drum No.	Coating System	Group No.	Description	Rating
18	1D	1	Peeling and rusting at chimes on both ends and at bungs. Rims quite worn with corrosion pits. Slight blistering along seam. Paint removed in spots on hoops and body with 50% showing rust spots. Moderate rust around bottom ring. Very dirty on bottom of drum with 2 sq.in. area rusting.	4
21	1D	1*	Cracked with some rusting at top chime. 80% completely peeled with bad rusting at bottom end. 7 holes through drum. Rims badly corroded. Marked rust blisters along seam. Paint removed in spots on hoops and body with 50% rust spots.	0
30	1Phosphate	2	Many very fine cracks at chimes and bungs but with no corrosion. Moderate wear on rims with slight corrosion. 3 black spots along seam. Sl-mod. wear on hoops with slight corrosion. Dirt on bottom with 1/2 sq.in. corrosion.	7
34	1P	2	Fine cracks along chimes but no corrosion. No cracks at bungs. Sl-mod. wear on rims with slight corrosion. One small blister on seam. Paint chipped off some areas of hoops with sl. corrosion. Dirt on bottom. Stain on top from leak at air space with some film removed.	7.5
37	1P	2	Fine cracks at chimes but no corrosion. No cracks at bungs. Sl-mod. wear on rims with slight corrosion. 2 black spots on seam. Sl-mod. wear on hoops with trace corrosion. Dirt on bottom with few rust spots on hoop.	7.5
40	1P	2	Very few fine cracks at chimes with no corrosion. No cracks around bungs. Wear on rims but no corrosion. Seam good. Worn to metal at several places on hoops but no rusting. Slight rusting around bottom rim.	7.5

* Empty drum stood on end on ground

Drum No.	Coating System	Group No.	Description	Rating
45	1P	2	Many fine cracks with onset of corrosion at chimes and small bung. Flaking and rusting between chime and large bung. Marked wear with moderate corrosion on lower rim. Moderate wear with slight corrosion on upper rim. Several small blisters along seam. Paint removed in small pieces from hoops and body with moderate corrosion. Very dirty on bottom with 3 areas corrosion - both ends and one hoop.	6
51	2Phosphate	3	Small cracks with moderate rust at chimes and bungs. Moderate wear with moderate corrosion at rims. Few rust blisters along seam. Sl-mod. wear on hoops with slight corrosion. Peeling with rust at 3 spots on body near lower rim. Very dirty on bottom with few small rust blisters at one end.	6
53	2P	3	Small cracks with beginning of flaking and rust at chimes. Moderate wear on rims with sl-mod. corrosion. Seam good. Moderate wear on hoops with slight corrosion. Moderate dirt on bottom. Application sags evident in film.	6.5
57	2P	3	Small cracks with beginning of peeling and rust at chimes and bungs. Sl. more peeling on plain end. Moderate wear on rims with sl-mod. corrosion. Seam good. Paint flaked off few places on hoops with slight corrosion. Moderate dirt on bottom with large area small rust blisters at one end. Application sags.	6.5
59	2P	3	Cracks with some peeling at chimes with two small rust areas. No cracks at bungs. Marked wear with sl-mod. corrosion on rims. Seam good. Sl-mod. wear on hoops with slight corrosion. Dirt on bottom with 2 sq.in. rust blisters and rusting at rims. Application sags.	6.5
62	2P	3	Fine cracks at chimes and small bung with beginning of corrosion. Worn to metal on lower rim with slight rust spotting. Moderate wear on upper rim with rust. Seam good. Moderate dirt on bottom. Film badly stained on bottom near end from fuel leak; removed in one area with rusting. Application sags.	6

Drum No.	Coating System	Group No.	Description	Rating
76	3Degrease	4	Fine cracks at chimes and large bung with beginning of corrosion. Small black and rust spots around small bung and few areas of both ends. Moderate wear with sl-mod. corrosion on rims. Beginning of corrosion on seam at hoops. Sl-mod. wear on hoops with trace corrosion. Sl-mod. dirt on bottom with tiny black spots and one area small black spots with blisters near end.	6.5
79	3D	4	Very fine hair cracks at chimes and bungs. Few small rust spots on other end. Sl-mod. wear on rims with slight corrosion. Seam good. Little wear on hoops with no corrosion. Moderate dirt on bottom with very tiny rust spots.	7
82	3D	4	No cracks at chimes or bungs. Few rust spots in small areas near chimes and at large bung. Moderate wear on rims with sl-mod. corrosion. Few marks along seam. Slight wear on hoops with trace corrosion. Sl-mod. dirt on bottom with tiny black spots. Fine rust pattern in area on one side of body.	6.5
86	3D	4	Few fine cracks at chimes on both ends. Few small rust spots around large bung. Moderate wear on lower rim with corrosion. Sl-mod. flaking on upper rim with slight corrosion. Two small rust spots on seam at hoop. Little wear on hoops with very slight corrosion. Sl-mod. dirt on bottom with very fine black spots.	7.5
88	3D	4	Many fine cracks with rust at chime on bung end. Fewer cracks at other end. Some flaking with rust at bungs. Moderate wear on rims with slight corrosion. Corrosion on edge of seam at hoops. Sl-mod. wear on hoops with small rust spots. Moderate dirt on bottom with very fine rust spots.	6
90	3D	4*	Many small rust spots on bung end. Few larger rust areas on other end. Marked wear on rims with marked corrosion. Few very small rust blisters along seams. Little wear on hoops with no corrosion.	5

* Empty drum stood on end on ground

Drum No.	Coating System	Group No.	Description	Rating
99	3Phosphate	5	Small cracks with rusting and beginning of flaking at chimes and bungs of bung end. More severe flaking and rusting at chime on other end. Moderate wear on rims with sl-mod. corrosion. Seam good. Slight wear on hoops with trace corrosion. Sl-mod. dirt on bottom with 3 sq.in. fine blisters at one end.	6
102	3P	5	Many fine cracks at chime on bung end. Fine cracks with rust at large bung. Severe flaking with rust at chime on other end. Marked wear on rim with moderate corrosion. Seam good. Slight wear on hoops with little corrosion. Slight dirt on bottom.	5
105	3P	5	Fine cracks at chimes both ends but none at bungs. Moderate wear on rims with sl-mod. corrosion. Seam good. Slight wear on hoops with slight corrosion. Slight dirt on bottom.	7
108	3P	5	Fine cracks at chimes but no corrosion. No cracks at bungs. Marked wear on rims with moderate corrosion. Seam good. Sl-mod. dirt on bottom.	7
110	3P	5	Cracking with flaking and rust at chimes and large bung. Moderate wear on rims with slight corrosion. Few rust spots on seam. Moderate wear on hoops with sl-mod. corrosion. Slight dirt on bottom with rust spot on hoop.	6
111	3P	5*	No cracks at chime or bungs on bung end. Trace rusting around chime on other end. Marked wear on lower rim with moderate rust spots. Moderate wear on upper rim with sl-mod. rust spots. Two small rust blisters along seam. Slight wear on hoops because stood on end.	7.5
122	4Degrease	6*	No cracks at chime or bungs on bung end. Moderate rust with some flaking on other end from standing. Moderate wear on rim with moderate corrosion. Very few small rust spots near seam. Little wear on hoops. Small rust spots on one area of body.	6

* Empty drum stood on end on ground

Drum No.	Coating System	Group No.	Description	Rating
125	4D	6	Fine cracks with beginning of rust and small area of flaking at chimes and bungs. Small rust spots at both ends. Moderate wear on lower rim with moderate corrosion. Little wear on upper rim with trace corrosion. Two rust spots on seam. Slight wear on hoops with trace corrosion. Large dent on one hoop from dropping but no lifting of film. Sl-mod. dirt on bottom with few rust spots.	6
128	4D	6	Fine cracks with beginning of rust at chimes and large bung. Many small rust spots on bung end and around small bung. Moderate wear on rims with sl-mod. corrosion. Seam good. Slight wear on hoops with little corrosion. Moderate dirt on bottom with fine rust no.1 blisters in one area near end.	6
132	4D	6	Fine cracks with few rust spots at chimes. Few rust spots at bungs. Many small rust spots on surface of plain end. Moderate wear on lower rim with sl-mod. corrosion. Slight wear on upper rim with trace corrosion. Few rust spots on seam. Little wear on hoops but tiny rust spots on body. Sl-mod. dirt on bottom with tiny black spots. Few rust blisters at one end.	6
134	4D	6	Fine cracks with beginning of rust at chime on bung end. Numerous small rust spots around large bung and on bung end. Few small rust spots on plain end. Sl-mod. wear on rims with sl-mod. corrosion. Seam good. Slight wear on hoops with little corrosion. Sl-mod. dirt on bottom with very fine rust spots.	6
142	4D	6	No cracks at chimes or large bung but small rust spots at small bung and on both ends. Slight wear on rims with very slight corrosion. Seam good. Slight wear on hoops with some small rust spots. Moderate dirt on bottom.	6
150	4Phosphate	7	Small flakes and rust from small cracks at chimes. Cracks with beginning of rust at bungs. Several rust spots on plain end where paint removed by handling. Moderate wear on rims with sl-mod. corrosion. Few marks along seam. Paint chipped off hoops in some spots with slight corrosion. Sl-mod. dirt on bottom with 1 sq.in. rust near end.	6

Drum No.	Coating System	Group No.	Description	Rating
154	4P	7	Rust spots and flaking from small cracks at chimes and bungs. Moderate wear on rims with sl-mod. corrosion. Few marks along seam. Paint chipped off hoops with slight corrosion. Paint chipped from body with rusting due to handling. Slight dirt on bottom with 3 sq.in. fine blisters at end.	6
156	4P	7	Small cracks with beginning of rust at chime on bung end. No cracks at bungs. Many fine cracks at chime on plain end. Moderate wear on rims with slight corrosion. Seam good. Paint chipped off hoops but no corrosion. Moderate dirt on bottom with 2 areas, 1 sq.in and 4 sq.in, rust blisters.	6.5
160	4P	7	Small cracks with beginning of corrosion at chimes; none at bungs. Rust spots on plain end where paint removed by handling. Marked wear on lower rim with moderate corrosion. Sl-mod. wear on upper rim with slight corrosion. Few marks along seam. Paint chipped off hoops with sl-mod. corrosion. Sl-mod. dirt on bottom with 2 sq.in. area small blisters at both ends.	6.5
162	4P	7	Flaking and rust from fine cracks at chimes and bungs. Mod-marked wear on rims with moderate corrosion. Few marks along seam. Paint chipped off hoops and parts of body with moderate corrosion. Sl-mod. dirt on bottom with rust spots at hoops.	6
170	5Degrease	8	No cracks at chime on bung end. One small crack at each bung with slight rust. Small rust spots near chime on plain end. Moderate wear with sl-mod. corrosion on rims. Few small rust spots along seam. Sl-mod. wear on hoops with trace corrosion. Sl-mod. dirt on bottom with area small rust blisters near end. Finish yellowed.	6.5
173	5D	8	Few fine cracks with beginning of peeling and rust at chime and bungs of bung end. Plain end good. Moderate wear on rims with slight corrosion. Few small blisters along seam. Little wear on hoops with slight corrosion. Little dirt on bottom. Some application sags. Finish yellowed.	7

Drum No.	Coating System	Group No.	Description	Rating
177	5D	8	Few fine cracks with trace fine flaking and corrosion at one area near chime and bung. Moderate wear with sl-mod. corrosion on lower rim. Sl-mod. wear on upper rim with slight corrosion. Few marks along seam. Little wear on hoops with no corrosion. Sl-mod. dirt on bottom with 1 sq. in. fine rust blisters. Finish yellowed.	7
180	5D	8	One fine crack at chime, none at bungs. Slight wear on rims with slight rust. Seam good. Little wear on hoops with slight rust. Little dirt on bottom but area fine blisters near one end. Finish yellowed.	8
182	5D	8	Fine cracks with beginning of corrosion and some flaking at chime and bungs on bung end. Small rust spots on plain end. Moderate wear on lower rim with moderate corrosion. Sl-mod. wear on upper rim with slight corrosion. Few marks along seam. Slight wear on hoops with slight corrosion. Sl-mod. dirt on bottom with 2 sq. in fine blisters at one end. Finish yellowed.	6.5
195	7 Wash Primer	9	Few small cracks with rust spots and peeling starting at chime and bungs on bung end. Many small cracks at chime on plain end. Moderate wear on lower rim with sl-mod. corrosion. Little wear on upper rim with trace corrosion. Many small rust blisters along seam. Moderate wear on hoops with moderate corrosion. Moderate dirt on bottom with one rust spot.	6.5
198	7W	9	Many fine cracks with beginning of rust and flaking at chimes. Larger cracks with rust at bungs. Sl-mod. wear on rims with slight corrosion. Small rust blisters along seam. No wear on hoops. Moderate dirt on bottom with 2 small corrosion patches, one at a scratch.	6.5
200	7W	9	Fine cracks with beginning of peeling at chimes on bung end. Few small rust spots around bungs and over surface. Small flaked cracks with rust on plain end. Moderate wear on lower rim with some corrosion. Slight wear on upper rim with little corrosion. Numerous small blisters some with rust along seam. Little wear on hoops with no corrosion. Dirt on bottom with several fine blisters at end.	6.5

Drum No.	Coating System	Group No.	Description	Rating
204	7W	9	Very fine cracks at chimes but no corrosion. No cracks at bungs. Slight wear on rims with slight rust. Small blisters along seam. Worn to metal on hoops but no rusting. Sl-mod. dirt on bottom.	7.5
206	7W	9	Cracking with flaking and rust at chimes and bungs. Moderate wear on rims with slight rust. Very small rust blisters along seam. Sl-mod. wear on hoops with slight rust spots. Moderate dirt on bottom with three 1 sq.in. rust areas.	6
223	5Phosphate	10	Small cracks with flaking and beginning of rust at chime and bungs on bung end. Very fine cracks on both ends. Sl-mod. wear on rims with slight corrosion. Seam good. Slight wear on hoops with little corrosion. Little dirt on bottom but fine blisters at one end. Finish yellowed.	6.5
225	5P	10	Fine cracks with beginning of flaking and rust at chime and bungs on bung end. Very fine cracks at chime on plain end. Sl-mod. wear on rims with slight rust. Few small rust spots along seam. Sl-mod. dirt on bottom. Finish yellowed.	7
231	5P	10	Flaking and rusting from fine cracks at chimes; slightly more severe on plain end. Rust areas around bungs. Moderate wear on rims with moderate corrosion. Several marks along seam. Small chipped areas on hoops with sl-mod. corrosion. Slight lifting from dent on hoop from dropping. Sl-mod. dirt on bottom with large area small blisters and some rust blisters at one end; stain from fuel leak at other end. Finish yellowed.	6
234	5P	10	Few very tiny cracks and rust spots at chime on bung end. No cracks at bungs or at chime on plain end. Moderate wear on rims with slight rust. Seam good. Slight wear on hoops with few rust spots. Moderate dirt on bottom. Finish yellowed.	7.5

Drum No.	Coating System	Group No.	Description	Rating
237	5P	10	No cracks at chimes. Few fine rust spots around large bung. Moderate number small rust spots on plain end. Moderate wear on rims with slight corrosion. Few black spots along seam. Slight wear on hoops with little corrosion. Sl-mod. dirt on bottom. Finish yellowed.	6.5
244	2Degrease	11	Flaking, peeling and rust at chimes. Cracks with rust at bungs. Few rust spots on surface of plain end. Marked wear on lower rim with moderate corrosion. Sl-mod. wear on upper rim with slight corrosion. Rust blisters along seam. Paint chipped off hoops in some places with sl-mod. corrosion. Two areas of blistering and peeling on body perhaps due to fuel drips. Dirt on bottom with 2 sq. in and 4 sq.in. rust blisters at ends.	5
248	2D	11	Peeling and rusting from cracks at chimes. Severe peeling at small bung. Moderate wear on rims with moderate corrosion. Many small rust blisters along seam. Paint flaked off hoops in some places but little corrosion. Sl-mod. dirt on bottom with 4 sq.in. small blisters at one end.	6
251	2D	11	Cracks with rust and starting to peel at chime on bung end. Fine cracks and few corrosion spots at chime on plain end and at bungs. Moderate wear on rims with slight rust. Few small blisters along seam. Paint removed from hoops in spots with rusting. Sl-mod. dirt on bottom.	5
254	2D	11	Small cracks some with rust at chime on bung end but none at bungs. Flaking with rust at chime on plain end with many small rust spots over surface. Marked wear on rims with moderate corrosion. Many small rust blisters along seam. Paint chipped off hoops and parts of body with small rust spots. Little dirt on bottom with 3 sq.in. medium blisters at one end.	5

Drum No.	Coating System	Group No.	Description	Rating
256	2D	11	Marked flaking and rusting from fine cracks at chimes and large bung. Peeling and rusting from small bung. Marked wear and corrosion on rims. Many small rust blisters along seam. Paint chipped off hoops and some places on body with rust spots. Sl-mod. dirt on bottom with large areas of rust spots and blisters at both ends.	4
258	2D	11*	Few cracks at chime on bung end. Lifting from corrosion in few areas especially near bungs. 100% severe corrosion on plain end from standing on end. Coating completely removed from rims by rust blisters not wear. Rust blisters along seam. Paint chipped off hoops with sl-mod. corrosion.	1
271	6Phosphate	12	Large cracks with peeling at chime from dropping drum on rim. Few small rust spots near chime and small bung. Rust area near large bung. Moderate wear on rims with sl-mod. corrosion. Few small rust blisters along seam. Scratches on hoops with slight corrosion. Two areas peeling on hoops from dropping drum. Slight dirt on bottom. Finish yellowed.	6
273	6P	12	One crack with flaking but no rust and one fine crack with beginning of rust at chime on bung end. Several small rust spots especially around small bung. Few small rust spots on plain end. Moderate wear on rims with sl-mod. corrosion. Seam good. Little wear on hoops with no corrosion. Sl-mod. dirt on bottom. Finish yellowed.	6.5
277	6P	12	Two 2 in. strips peeling at chime near bung and corrosion around bungs. Small black spots over surface on plain end. Sl-mod. wear on rims with slight corrosion. Few marks along seam. Slight wear on hoops with trace corrosion. Sl-mod. dirt on bottom with 2 small rust spots. Finish yellowed.	6.5

* Empty drum stood on end on ground

Drum No.	Coating System	Group No.	Description	Rating
279	6P	12	Badly rusted one area near chime and one area near large bung and many small corrosion spots on bung end. Few small cracks with slight rust at chime on plain end. Upper rim badly worn with marked corrosion spots. Seam good. Slight wear on hoops with no corrosion. Little dirt on bottom. Finish yellowed.	5
282	6P	12	Many small rust spots with larger areas completely flaked off on bung end. Few small rust spots near chime on plain end. Moderate wear on rims with moderate corrosion. Few small rust spots along seam. Paint removed from hoops in small chips. Many small rust spots on body with lifting at 2 dents where drum dropped. Little dirt on bottom. Finish yellowed.	4

APPENDIX C

Condition of Interiors of Fuel Drums in 1968

Drum No.	Coating System	Contents	Description	Rating
2	W1	Avgas	Filiform corrosion over all first ring and top of second. Solid 5 in. wide white strip at 6 o'clock with rust patches in hoops and first ring. 5 in. strip dense 1/4 in. white spots in air space.	3
6	W1	Avgas + Water	8 in. white strip with heavy 1/2 in. spots where water lay. White strip with rust in air space.	4
9	W1	Jet Fuel	Two patches 1 in. white blisters (1-1/2 in. in hoop) at 6 o'clock. White blisters both sides first hoop in air space. Some blisters and rust spots in bottom*. Black stain under film.	8
20	W1	Jet Fuel + Water	5 in. strip 1/2 in. white spots where water lay with heavy rusting and peeling in hoops, peeling in bottom ring. 5 in. strip white spots and rust patches in air space. Bottom and seam good.	2
11	W1	None	White spots with some black spots and rust blisters in bottom ring. Areas of rust blisters on bottom. Rusting in seam.	7
13	W1	None	Areas of dense white spots in rings. Few rust blisters in first hoop. Some large rust spots and blisters on bottom near sides at two locations.	7
32	P1	Avgas	6 in. strip in first ring and 2 in. in 2nd and 3rd of few 1/16 in. white spots. Reddish brown fuel deposit except in air space.	9
35	P1	Avgas + Water	4 in. strip in first ring and 9 in. in 3rd and hoops white film removed with rusting where water lay. Rust blisters in center and white spots on sides of air space. Slight rusting in seam.	2

* In Appendix C, bottom refers to the inner plain end of the drum when standing in the upright position for examination.

Drum No.	Coating System	Contents	Description	Rating
46	P1	Jet Fuel	2 in. strip with few white spots and few black spots (may be fuel deposit) at 6 o'clock. Bottom and seam good.	9
41	P1	Jet Fuel + Water	5-8 in. strip with 50% removal and rusting where water lay. 5 in. strip small white spots, dense, in air space with 2" x 3" heavy rust blisters in 3rd ring. Heavy fuel deposit except in air space.	2
28	P1	None	Rust blisters and some whitening under film which broke in 3 places at a dent. Rusted dent in second hoop. Moderate rusting in seam.	5
48	P1	None	Film poorly applied. Generally good condition except rusting at dent in 3rd ring and med-dense yellowish blisters in first ring. Sl-moderate rusting in seam.	8
69	P2	Avgas	Some rusting on seam. Film overspray looks like microscopic blistering.	8
54	P2	Avgas + Water	8 in. medium white strip in first ring, 4 in. in 3rd and 10 in. in hoops with rusting under film. Light white spots near air space. Moderate rusting in seam.	6
66	P2	Jet Fuel	Faint 6 in. strip #8 rust blisters in first ring. Slight rust in seam. Few 1/2 in. white spots in bottom.	9.5
60	P2	Jet Fuel + Water	5 in. medium white strip, 8 in. in hoop where water lay. 4" x 5" white spots with rust blisters in first ring of air space. Slight rust on seam at hoops.	6
65	P2	None	Rusting on seam only.	9
71	P2	None	Large white spots and rusting in 5 in. length of second hoop.	7
72	P2	None	Small blisters down one side and some rusting on bottom near sides. Rusting on seam especially in first ring.	7

Drum No.	Coating System	Contents	Description	Rating
77	G2	Avgas	3 in. strip of black spots or stain in rings at 6 o'clock.	9.5
80	G2	Avgas + Water	8 in. strip in rings, 10 in. in hoops completely rusted where water lay. 5 in. of rust in first hoop on one side.	1
83	G2	Jet Fuel	3 in. strip black spots in rings with some rust nodules in 2nd and 3rd at 6 o'clock. 4 in. strip light-moderate rust blisters in air space. Purple fuel deposit in lower half of drum.	5
85	G2	Jet Fuel + Water	5 in. strip in rings, 8 in. in hoops of rust where water lay. Large rust blisters in first ring and hoop of air space. No.6 rust blisters in 1st and 3rd rings at edge of air space. Few no.6 rust blisters on bottom.	2
73	G2	None	Rusting in two dents on hoops, otherwise excellent.	9.5
92	G2	None	2 sq.in. of filiform corrosion in first ring, otherwise excellent.	9.5
98	P3	Avgas	Slight rust at seams in hoops, otherwise excellent.	9.5
101	P3	Avgas + Water	Large white area, especially in 2nd ring, and some light rust stain in hoops where water lay. 7 in. cream strip near one side of air space; heavy in first ring, lighter in others. Poor film application led to sags, many of which have popped with rust in the first ring.	4
104	P3	Jet Fuel	2 in. strip of brown stain spots at 6 o'clock. 4 in. heavy white strip with red spots near one side of air space.	7
107	P3	Jet Fuel + Water	7-1/2 in. heavy white strip in rings, 10 in. in hoops, where water lay. 5 in. lighter white strip in first ring and hoop and black spots in first and second rings near one side of air space. 3 sq. in. white area in first hoop on one side.	6

Drum No.	Coating System	Contents	Description	Rating
114	P3	None	Film cracked over 6" x 1/2" dent in second ring, otherwise excellent.	9
117	P3	None	Sags in film at hoops yellowed. White area 2 x 10 in. in hoop. 4 in. medium rust strip on one side of seam. Yellowish blisters on bottom near edges with rust in center.	5
126	G3	Avgas	Excellent condition.	10
129	G3	Avgas + Water	8 in. light white strip at top, 5 in. at bottom, 9 in. in hoops, with rusting in center where water lay. 5 in. white strip, 7 in. and heavy with rust blisters in hoops at air space. Few patches of rust under film near rim on both sides.	5
131	G3	Jet Fuel	Stain line at 6 o'clock, otherwise excellent.	9.5
135	G3	Jet Fuel + Water	3 in. white strip at top, 10 in. at bottom with heavy rust in 2nd hoop and 3rd ring, rust nodules in 1st hoop, where water lay. 8 in. medium white strip at top, 6 in. at bottom, with 1/4 in. rust blisters in 1st ring, 1/2 in. white spots 2nd ring, black spots in 3rd ring at air space. Some rust on bottom near sides.	4
143	G3	None	Rust in bottom from collected water. Remainder excellent.	6
144	G3	None	Excellent condition.	10
151	P4	Avgas	Dents in 3rd ring with one rusting. Seam good.	8
153	P4	Avgas + Water	5 in. light white strip at top, 2 in. at bottom, where water lay. Rusting at dent in first ring. Seam good.	8
157	P4	Jet Fuel	Lifting at dent in first ring, slight stain at bottom, otherwise excellent.	8
159	P4	Jet Fuel + Water	3 in. medium stain, rusting at dent in 2nd hoop where water lay, otherwise excellent.	8

Drum No.	Coating System	Contents	Description	Rating
163	P4	None	1/2 sq. in. peeling from dent in first ring near air space. Very slight rusting of seam.	9
171	G4	Avgas	2 in. black stain strip in rings, 5 in. in hoops with rust blisters and filiform corrosion in strip at bottom at 6 o'clock.	7
174	G4	Avgas + Water	7 in. stain strip at top, 4 in. at bottom, with some tiny rust blisters in rings and dense rust blisters in hoops where water lay. Slight-medium fuel stain except in air space.	6
176	G4	Avgas	3 in. strip of 1/2 in. white and black spots at 6 o'clock.	7
179	G4	Avgas + Water	White strip running from 11 in. wide at bottom to half way of first ring, 11 in. in 2nd hoop, 7 in. in 1st hoop where water lay. Fuel stain except at air space.	8
189	G4	None	Seam rusted at bottom.	8
190	G4	None	Few med. rust spots at top edge of 1st ring, few in remainder of 1st ring. Some rust at seam.	6
194	W5	Avgas	3 in. light white strip, 6 in. in hoops, with rust underneath at 6 o'clock. 3 in. strip med-dense rust blisters in 1st two rings at air space. Slight rusting at seam in 3rd ring. First stage of rusting under film over all drum.	5
197	W5	Avgas + Water	6 in. strip filiform corrosion and whitening in rings, 8 in. dense rusting with peeling in hoops, where water lay. 8 in. strip filiform corrosion and blisters, 10 in. in hoops, on one side near air space and continuing onto bottom.	3
201	W5	Jet Fuel	1/4 in. med.dense black spots all over drum. Some #8 rust blisters on bottom near edges. Slight rust at seams.	8

Drum No.	Coating System	Contents	Description	Rating
203	W5	Jet Fuel + Water	4 in. light rust strip, 7 in. in hoops and 3" x 4" blisters in 3rd ring where water lay. Light rust under film in first ring and hoop at air space. Black or rust spots over all drum. Few patches 1/4" white blisters in 1st ring and hoop on side.	5
211	W5	None	Trace rusting under film on half of drum. Some rust and black spots under film on bottom. Slight rusting at seam in 3rd ring.	5
213	W5	None	Few blisters in patch on one side. Very small rust specks in first two rings.	7
222	P5	Avgas	Some rusting at seam in 2nd ring.	9
226	P5	Avgas + Water	Film peeled 4 in. 1st ring, 12 in. 2nd, 14 in. in hoops where water lay. 7 in. light white strip with few 1/8 in. rust blisters in air space. Light rust under film over all drum and filiform corrosion 10 in. strip on one side and heavy patches on bottom near sides.	1
235	P5	Jet Fuel	Sl-moderate rusting at seams. One patch very small rust blisters, otherwise excellent.	9
238	P5	Jet Fuel + Water	2 in. light rusting in rings. 4 in. heavy rusting in hoops where water lay. Rusting under film on one side near air space. One patch rust blisters on bottom. Trace rusting at seams.	6
217	P5	None	Dense rust under film. Heavy rust patches in hoops on one side. Rust on bottom.	2
218	P5	None	Rusting under film in large patches. Film peeled back from 3 dents which have rusted. Bottom badly rusted from 2 in. collected water. Rusting at seam.	2

Drum No.	Coating System	Contents	Description	Rating
245	W6	Avgas	Trace of deposit 3 in. first ring, 4 in. in hoops at 6 o'clock. Flat white dots in hoops at air space. Black specks under film all over.	8
247	W6	Avgas + Water	Film stained in 1" x 5" patch on one side. Black specks under film all over.	9
250	W6	Jet Fuel	2 in. black stain with few rust blisters in first ring, 4 in. rusting in hoops at 6 o'clock. Black and white faint spots in first ring, 6 in. dense white specks in hoops on one side near air space.	6
253	W6	Jet Fuel + Water	6 in. whitish strip with 3 patches of rust 1/4 to 1-1/2 sq.in. mostly in first ring and second hoop where water lay. 5 in. whitish strip with 2 1/4" rust blisters in air space.	5
257	W5	None	Few black spots in first ring. Slight rust at seam in 3rd ring. Hole in bottom from outside.	9*
260	W5	None	Few large rust blisters on bottom near sides. Some rust at seam. Hole in bottom from outside.	8*
270	P6	Avgas	Few 1/2 in. black stains in rings and white strip under lip in first ring at 5 o'clock. Film slightly cracked at dent in 2nd ring. Slight rust in seam at hoops. Generally excellent.	9
274	P6	Avgas + Water	5 in. at top to 2 in. at bottom light brown stain where water lay. Few-medium rust blisters up to 1/2 in. in each ring at air space. Filiform corrosion extending from seams.	5
276	P6	Jet Fuel	Very good condition.	10

* Perforation from exterior

Drum No.	Coating System	Contents	Description	Rating
280	P6	Jet Fuel + Water	Slight black stain under film in top ring, rust blisters in hoops, 3 in., and bottom of 3rd ring where water lay. 5 in. strip rust blisters up to 3/8" med-dense on one side near air space.	5
283	P6	None	Rust at dent in bottom. At seam trace rust in first ring, slight rust in 2nd, moderate rust in 3rd. Otherwise excellent.	9
284	P6	None	4 in. patch small rust specks in first ring. 2 dents in 2nd hoop: one rusted, one lifted but no rust.	8

APPENDIX D

Condition of Exteriors of Fuel Drums in 1968

Drum No.	Coating System	Group No.	Description	Rating
2	1Degrease	1	6 sq.in. rust blisters on bung end. Cracking and peeling near chime on plain end.	4
6	1D	1	Peeling on both ends. 3 sq.in. blisters both ends of bottom side. Body fair. Rusting on lower rim.	3
9	1D	1	6 sq.in. blisters one end of bottom side. Dent with rusting on second hoop, bottom side. 1 sq.in. peeling with rusting in each ring. Rusting on upper rim. Cracking and peeling at chimes on both ends.	4
11	1D	1*	Heavy rusting on both ends. Large rust blisters in first two rings. Seam rusted. Rusting on both rims.	1
13	1D	1*	Almost no paint on plain end; bung end not as bad. 6 sq.in. rusting in first ring near edge. Very large peeled area with rusting on body.	1
20	1D	1	Rusting near chimes on both ends. Patch blisters on bottom side. Rusting on both rims and around bungs.	4
28	1Phosphate	2*	Dent in 2nd hoop with 1 sq.in. rusting. 18 in. rusting along seam. Blistering, wrinkling and flaking to primer on body.	4
32	1P	2	3 sq.in. blisters one end of bottom side. Slight cracks at chimes both ends.	8
35	1P	2	Patches of blisters both ends of bottom side. Cracks at chime on plain end.	8
41	1P	2	Patches of blisters both ends of bottom side. Slight cracks at chime on plain end.	8
46	1P	2	One area popped blisters one end of bottom side. Few cracks at chime on plain end.	8.5

* Empty drum stood on end on ground.

Drum No.	Coating System	Group No.	Description	Rating
48	1P	2*	Peeling to primer in large patches on plain end. Rusting on both hoops. Slight rust on seam.	5
54	2Phosphate	3	One half plain end with rust and rust blisters. Slight rusting at chime on bung end.	5
60	2P	3	3 sq.in. blisters and rust blisters lower side of bung end.	8
65	2P	3*	Plain end in poor condition with rust patches over half area. Some rusting on bung end.	4
66	2P	3	5 sq.in. rust blisters on bung end. Some rust blisters at chime and on surface of plain end.	6
69	2P	3	Few medium rust blisters at small dent one end of bottom side. Cracking with slight rust at chimes on both ends.	7
71	2P	3*	Plain end badly rusted. Popped rust blisters on body. Rust blisters at chime near large bung.	3
72	2P	3*	Holes in plain end.	0
73	3Degrease	4*	Marked rust spots on plain end and along seam.	3
77	3D	4	Two areas fine rust blisters on plain end. Some sags on body in 3rd ring.	8
80	3D	4	Strip of few rust blisters on bottom side. Bung end good.	8
83	3D	4	Strip of few rust blisters on bottom side. Bung end good.	8
85	3D	4	Two patches few small rust blisters on bottom side. Bung end good.	8
92	3D	4*	12 and 6 in. rusting at chimes bung and plain ends. 3 sq.in. and 5 sq.in. patches of rust on plain end.	5

*Empty drum stood on end on ground.

Drum No.	Coating System	Group No.	Description	Rating
98	3Phosphate	5	Cracking at chime on bung end. Cracking with 40% rust at chime on plain end.	6
101	3P	5	Cracking and peeling around bungs. Cracking at chimes on both ends. 8 sq. in. popped blisters on bottom side one end.	4
104	3P	5	Slight cracks at chimes on both ends.	8
107	3P	5	Grey specks on side, otherwise good.	9
114	3P	5*	Few rust blisters on half plain end. 3 patches rust blisters on bottom side near plain end.	5
117	3P	5*	Rusting on side 3 in. up half-way around drum.	6
126	4Degrease	6	Cracks at chimes on both ends with rust at plain end. Few-medium fine rust blisters or specks over all drum.	4
129	4D	6	Rust blisters at chimes on both ends. Rusting with blisters and stain on plain end. Fine pinhole rusting over all drum.	3
131	4D	6	Cracking with rust at chime on bung end, rust stains 30% of chime on plain end. Strip of fine rust blisters on bottom side.	6
135	4D	6	Popped rust blisters med-dense over all plain end. Fine rust blisters along seam. Cracking with rust blisters at chime on bung end. Few fine rust blisters on bottom side.	4
143	4D	6*	Rust over all plain end. 1/2 sq.in. small rust blisters on bung end. Rust blisters on half side in 3rd ring.	3
144	4D	6*	Rust over all plain end. 5 sq.in. heavy rust in 3rd ring. Popped rust blisters on hoop.	3

* Empty drum stood on end on ground.

Drum No.	Coating System	Group No.	Description	Rating
151	4Phosphate	7	Cracks with rust at chimes on both ends. 4 sq.in. rust spots on bottom side in first ring.	7
153	4P	7	Cracks at chimes on both ends. 4 sq.in. rust patch on bung end. Some rusting on plain end. Dirt on bottom side.	6
157	3P	7	Cracks with rusting at chimes on both ends. 30% rust blisters on plain end. 3 areas heavy cracking on bung end. Dirt on bottom side.	5
159	4P	7	Cracks with rusting at chimes on both ends. 3 sq.in. fine rust blisters on both ends. One long cut with rust on plain end. Dirt on bottom side.	6
163	4P	7*	Medium rust blisters on plain end, also 5 cracks 1-1/2 in. long. Many scrapes on body with rusting.	6
171	5Degrease	8	8 in. strip med-dense rust blisters on bottom side. Ends good.	8.5
174	5D	8	6 in. strip fine pinhole rusting, few on body, heavy on hoops on bottom side; fine pinhole rusting on hoops on upper side. Ends good.	6
176	5D	8	Few rust blisters at chime on plain end. Patches of blistering from primer on bottom side. Bung end good.	8.5
179	5D	8	6 in. strip blisters with rusting on bottom side; 12 in. on hoops. Few rust blisters on bung end; plain end good.	6
189	5D	8*	2 in. strip blisters in first ring. Rusting 1-5 in. up on 3rd ring.	5
190	5D	8*	Plain end badly rusted with few fine rust blisters in first ring. 7 in. rust spots on one side.	4
194	7Wash Primer	9	Cracking at chimes on both ends with 40% rusting. 18 in. strip grey mottling with center small blisters and some rust on upper side.	6

* Empty drum stood on end on ground.

Drum No.	Coating System	Group No.	Description	Rating
197	7WP	9	Cracking at chimes on both ends with peeling and rusting. 12 in. strip grey mottling with three 1 in. patches fine rust blisters on upper side.	5
201	7WP	9	Cracking at chimes on both ends with some peeling on bung end. 12 in. strip erosion with med-dense rust specks on upper side.	6
203	7WP	9	Few cracks at chime on bung end. Rust blisters on plain end and at seam. 10 in. strip grey mottling with blisters and rust blisters on upper side.	5
211	7WP	9*	Plain end badly rusted and heavy rusting along seam. Rusting 2-1/2 in. up on 3rd ring.	2
213	7WP	9*	Plain end badly rusted. Peeling with rust at chime near large bung. Rust blisters along seam and in first and 3rd rings.	2
217	5Phosphate	10*	Plain end moderately rusted with med-dense blisters. 2 in. strip rusting on sides at both ends.	4
218	5P	10*	Plain end badly rusted. Rusting along seam. 2 sq.in. blisters in 3rd ring. Rusting on side at lower end.	2
222	5P	10	Cracking at chimes on both ends with rust blisters on plain end. 8 in. strip grey specks on side.	7
226	5P	10	Slight rust cracking at chime on bung end and patch rust blisters. Popped rust blisters on plain end. 12 in. strip grey specks on side.	7
235	5P	10	4 sq.in. fine blisters on bung end. Popped rust blisters on plain end. 12 in. strip grey specks on side.	7
238	5P	10	10 sq. in. rust blisters near chime on bung end. Plain end good. Grey specks on side.	8

* Empty drum stood on end on ground.

Drum No.	Coating System	Group No.	Description	Rating
245	2Degrease	11	Cracking with rust at chimes on both ends, heavier rust on plain end. 3 sq. in. patch rust blisters on both ends. Rusting on side near lower end.	5
247	2D	11	Cracking with rust at chimes on both ends. Rusting on side near lower end.	6
250	2D	11	Cracking with rust at chimes on both ends. Moderate rust blisters on plain end. One patch rust blisters in first ring on upper side.	6
253	2D	11	Cracking with rust at chimes on both ends. 4 sq.in. rust patch on plain end. Rusting around bungs.	6
257	2D	11*	Holes in plain end. Bung end badly rusted. Fine rust specks over all body.	0
260	2D	11*	Hole in plain end but body in good condition.	0
270	6Phosphate	12	Cracking at chime on plain end with little rust. Peeling at chime on bung end with rust specks. 12 in. strip red mottling on side.	5
274	6P	12	Rust blisters at chime on plain end. Cracking with rust at chime on bung end. Some rust on seam. 12 in. strip red mottling on side.	5
276	6P	12	Rust blisters at chime on plain end. Bung end good. Few small rust blisters in 3rd ring. Red mottling on side.	7
280	6P	12	Two patches rust near bungs and peeling with rust at chime on bung end. Few rust blisters at chime on plain end. Few red mottled spots on side.	5
283	6P	12*	Both ends badly rusted. Rust blisters along seam. Rusting 2 in. up side at lower end.	3
284	6P	12*	Plain end badly rusted. Seam rusted. Rust strip up side 1-7 in. in 3rd ring. 1 sq.in. rust blisters in first ring. Red mottling on sides.	3

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* Empty drum stood on end on ground.

APPENDIX E

GROUP ON DRUM STORAGE OF FUEL

Name	Affiliation
Mr. J.K. Bell (deceased)	Dept. of National Defence, Directorate of Vehicle Development
Mr. J.W. Black	Dept. of National Defence, Directorate of Vehicle Development
Dr. J.W. Broughton (deceased)	National Research Council, Fuels and Lubricants Laboratory
F/L H.F. Burns	Dept. of National Defence, Air Materiel Command
Dr. D. Caplan	National Research Council, Corrosion Laboratory
Mr. D.A. Dennis	National Research Council, Building Materials Section
Mr. R.G. Grimsey	Dept. of National Defence, Royal Canadian Navy
Mr. John Harris, Chairman 1954-1957	National Research Council, Building Materials Section
Mr. R.A. Hill	Dept. of National Defence, Directorate of Vehicle Development
F/S O.B. Groskorth	Dept. of National Defence, Air Materiel Command
Mr. W.A. Himmelman	Imperial Oil Limited, Research Department
Dr. C.Y. Hopkins	National Research Council, Protective Coatings Laboratory
S/L H.J.M. Londeau	Dept. of National Defence, Air Force Headquarters

Name	Affiliation
Mr. J. D. O'Connor	Dept. of National Defence, Defence Research Board
Mr. B. I. Patterson Secretary	National Research Council, Fuels and Lubricants Laboratory
Mr. H. Racicot	Dept. of National Defence, Directorate of Vehicle Development
Mr. G. W. Rowley	Dept. of National Defence, Defence Research Board
F/L A. V. Rugenius	Dept. of National Defence, Air Materiel Command
W/O J. O. Smith	Dept. of National Defence, Air Materiel Command
W/O R. H. Smyth	Dept. of National Defence, Air Materiel Command
Mr. E. G. Ulbricht	Imperial Oil Limited, Research Department
S/L D. C. Wilson	Dept. of National Defence, Air Force Headquarters
Maj. A. E. Wisking	Dept. of National Defence, Army