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DESIGN CHANGE BENEFICIAL IN REDUCING DOMESTIC HOT WATER TANK CORROSION

by

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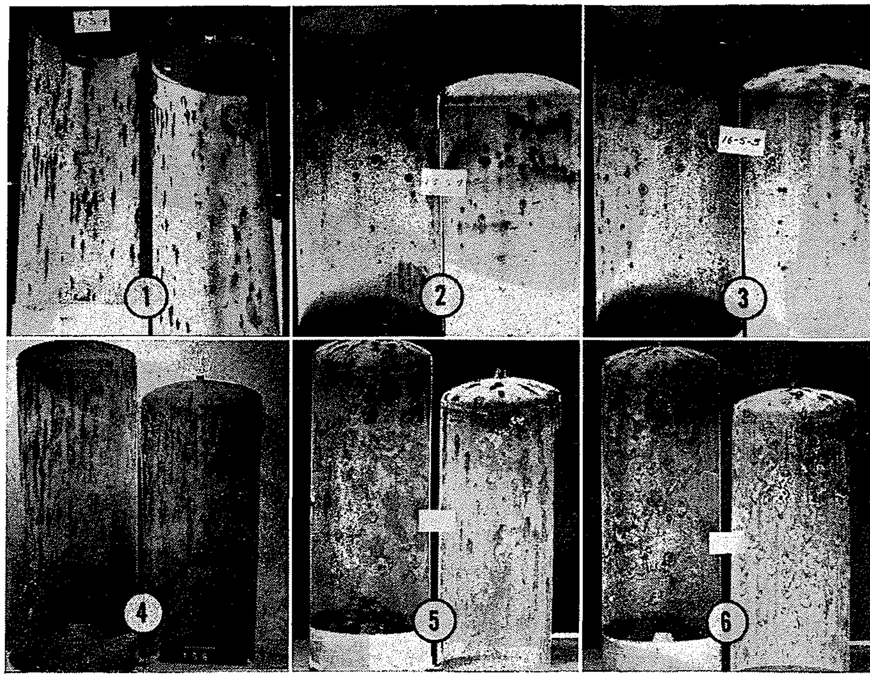

Figure 1—Appearance of tanks after failure at controlled temperatures. Example 1, 23 months at 170 F, Example 2, 17 months at 170 F, Example 3, 20 months at 170 F, Example 4, 80 months at 150 F, Example 5, 66 months at 150 F and Example 6, 60 months at 150 F. Examples 1 and 4 were from the Brantford Project; Examples 2 and 5 from the Belleville Project and Examples 3 and 6 from the Peterborough Project.

Long-Term Tests Show

Design Change Beneficial In Reducing Domestic Hot Water Tank Corrosion★

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FAILURE by corrosion of galvanized domestic hot water storage tanks, a familiar and annoying occurrence to so many householders, is responsible for an economic loss in Canada of several million dollars every year. Because tanks were being replaced in large numbers in post-war housing projects, sometimes within the first year of operation, the Division of Building Research at the request of Central Mortgage and Housing Corporation undertook in 1950 studies of the causes of failure.

The initial investigation involved the detailed physical and metallographic examination of a large number of corroded tanks from a number of localities in Ontario.[1] Subsequently two series of field experiments were planned.

Two Series of Experiments

Series A experiments involved investigation of primary factors of temperature and rate of water consumption with water supplies available at the three localities of Brantford, Peterborough and Belleville.

Series B experiments were planned to investigate the secondary factors of design involving the heater and piping and the resulting conditions of operation of the hot water system as they affected the corrosion of the tanks by the water in Windsor, Ontario.

In Windsor, unusually severe corrosion of galvanized hot water tanks was experienced in two CMHC projects involving 1000 tanks. Half of these were installed in project houses completed in 1948 where the hot water system consisted of No. 30 galvanized tanks, galvanized pipe and 750-w immersion heaters. The remaining half was installed in project houses completed in 1949 where the hot water system consisted of No. 30 galvanized tank, copper piping (including a copper dip tube) and a 750-w immersion heater. After a year there were failures by corrosion of tanks in both projects. Greater frequency of failures in the 1949 project reflected the influence of copper piping. In the 1948 project 65 out of 450 tanks developed leaks in the first year.

Types of Heater Significant

Records of performance of different types of systems in the Windsor area revealed the significant fact that where the tanks were heated by 3 kw side arm heaters equipped with a manual "on" and "off" switch, service life of the tank was much longer than in the cases where the tank was heated by an immersion heater of small capacity.

Series B studies also involved checking effectiveness of corrosion inhibitors such as polyphosphate and silicate in preventing the corrosion of the tanks in this locality.

No attempt was made in either series to observe the corrosion of the piping itself which was copper in some houses and galvanized iron in others.

This article reports results of these two series of field experiments.

Experimental Data

All studies involved complete domestic hot water systems installed in occupied houses in normal use.

Series A

All tanks involved in Series A tests were made to specifications of the Hydro-Electric Power Commission of Ontario, designated as 030-1A. They were equipped with two strap-on heaters rated at 800-w each controlled by individual thermostats. Three inches of glass wool insulation was used around the tank. Ten such units were installed in each of the three localities. Half of the units were controlled at 150 F or 160 F and the remaining half at 170 F. Hot water consumption was measured by means of a water meter installed in the cold water supply to the tank.

Copper piping was used in the projects at Belleville and Peterborough; galvanized pipe was used in Brantford. Where copper piping was used, the hot water outlet from the tank was connected with a 6-foot length of ½-inch galvanized iron pipe. The water supply to these units was the regular town supply and analyses given by Leverin[2] give the general type of water involved.

This study was continued for about 6½ years. Many of the tanks had failed earlier. All tanks were removed when they failed or at the end of the 6½-year period and examined physically and metallographically as described in a previous paper.[1]

Series B

In the two Windsor projects, 50 houses were selected where the hot water systems were altered for the purpose of these experiments. All tanks were replaced with new No. 30 heavy duty galvanized tanks and insulated as before. In a number of these the 750-w immersion heaters were replaced with 3 kw side arm heaters and equipped with an on-off switch operated in the kitchen along with an indicator light which shows when the heater is "on."

Copper piping was replaced with galvanized pipe for a length of about 3 feet from the tank including the dip tube. In a number of these systems a simple dispenser was provided to feed about 10 ppm of either polyphosphate or silicate. Detail of the systems is shown in Table 1.

After 5 year's service all 50 tanks from the two projects were removed and examined.

★ Revision of a paper presented under the title "Corrosion of Domestic Hot Water Tanks" at a meeting of Canadian Region Eastern Division, National Association of Corrosion Engineers, Montreal, November 14-15, 1960.

Temperature, Copper Pickup and Galvanizing Defects Important

Results and Discussion

Series A

1. There was distinct difference in appearance of the pitting corrosion for each locality as seen in Figure 1.
2. Service life of the tanks varied significantly even when identical installations in one locality were compared.
3. There was an indication that as temperature increased the corrosion rate also increased. This was very definite in the case of tanks from Brantford (Figure 2). Hoxeng and Prutton[3] and Weast[4] came to similar conclusions.
4. Rate of consumption of hot water varied threefold when considering all the units and twofold when considering houses with the same number of occupants. This factor did not seem to influence the corrosion rate. This also was found by Weast.[4] When consumption of hot water from units controlled at 170 F was plotted against the number of occupants in the house (Figure 3), there seemed to be a trend indicating a decrease in the consumption per house as the number of occupants increased. This was a surprising result.
5. Evidence from the metallographic examination was much the same as was obtained in the preliminary work reported.[1] Micrographs from tanks in service in Brantford indicated that there was a reversal of polarity of the steel and zinc. This is in support of the measurements made by Hoxeng and Prutton[3] and Guest.[5] There is also evidence of fissures and separation in the zinc alloy layers. Although the rate of corrosion of the tanks was about twice as rapid at 170 F as at 150 F the micrographs of the tank surfaces at the two temperatures do not reveal differences in the pattern of corrosion (Figure 4).
6. Severe corrosion and early failure was experienced with all tanks operated at the high temperature even though galvanized piping was used in Brantford. This result suggests that copper piping was not the major factor in contributing to the corrosion of these tanks, although it is suspected that the influence of copper piping varies with the type of water used.[6] In Windsor this appeared to be a more important factor just as Newell[7] had found in the case of some New England waters.
7. Thickness of the zinc coating on these tanks varied from 3.5 to 5.5 mils with an average of 4.3 mils. There was no correlation between the zinc thickness and the service life of this group of tanks.

Series B

Results of these tests after 5 years' service can be summarized as follows:

1. Tanks heated by side arm heaters and having galvanized piping showed very little corrosion and appeared in condition to give many more years of service. There was no difference between those inhibited with polyphosphate and those not so protected.
2. Tanks heated by side arm heaters and having copper piping showed more corrosion than those with galvanized piping. Where silicate inhibitor was used there appeared to be less corrosion.
3. Where small immersion heaters were used the corrosion was severe whether copper or galvanized piping was used. Inhibitors in these systems helped reduce corrosion as compared to the identical systems without inhibitor. Although the appearance of pitting corrosion was different with the different inhibitors, it was impossible to determine whether one was more effective than the other in preventing corrosion. It is not certain that the addition of inhibitors was continuous throughout the 5-year period; also, from the work of the American Gas Association,[8] it would seem that the concentrations of inhibitors used were too low for effective protection.
4. Figure 5 shows micrographs of the corroded and uncorroded edges of the sample tanks removed from Windsor. The pattern of the corrosion attack on the zinc, zinc-iron layers and steel interface is the same as that observed previously. The tanks heated by side-arm heaters and having galvanized pipe were corroded least, with an irregular attack on the zinc-rich layer. Tanks heated by side-arm heaters and having copper piping showed increased attack with fissures and pits in the zinc-iron layers and complete lifting of the galvanized layer from the base. Finally, tanks heated by immersion heaters showed very serious disintegration and removal of the zinc-iron layers. Inhibitors had no apparent effect on the pattern of corrosion attack revealed in these micrographs.

General Conclusions

The study at Peterborough, Brantford and Belleville showed that temperature was an important factor in the corrosion of hot water tanks. Reducing the temperature by as little as 10 degrees would certainly add years of service life to the tanks, especially in Brantford.

The study at Windsor showed that design of the hot water system and the resulting manner of operation has great effect upon the extent of tank corrosion. The change from a small capacity immersion heater to a large capacity side arm heater combined with a manual on-off switch was the most effective single factor in decreasing the corrosion of the galvanized tanks in this locality.

Abstract

Corrosion of galvanized tanks was studied in domestic installations in rental housing projects of Central Mortgage and Housing Corporation at Peterborough, Belleville and Brantford, Ontario where sample tanks of the Ontario Hydro-Electric Power Commission were used and at Windsor, Ontario where regular commercial tanks were used. In the first series it was shown that temperature was an important factor affecting the corrosion. In the series conducted at Windsor it was shown that when 3-kw side-arm heaters were used instead of small immersion heaters the design change was the greatest single factor in reducing corrosion.

Copper piping was shown to have an influence upon the corrosion, especially if a copper dip tube was used inside the tank. Results from tests involving corrosion inhibitors were inconclusive, perhaps because the concentration of about 10 ppm was too low.

Micrographs of the galvanized coatings show that the corrosion attack was very irregular, starting with fissures and separating the zinc-iron layers from the base. These fissures appear even in the uncorroded edges indicating they are produced in the galvanizing process and that changes in this process may improve the corrosion resistance. Reversal of potential between the steel and the zinc also is apparent in some micrographs. 7.5.5

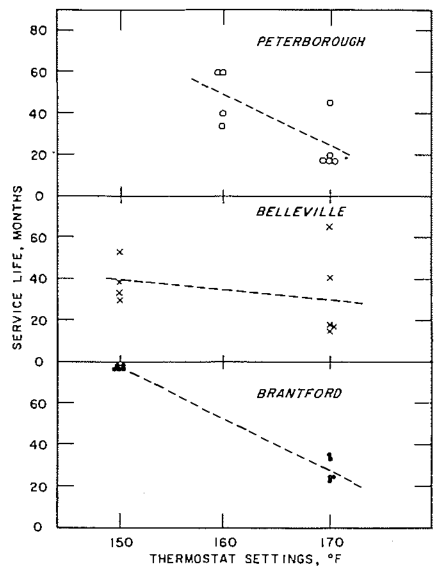

Figure 2—Service life of tanks controlled at different temperatures.

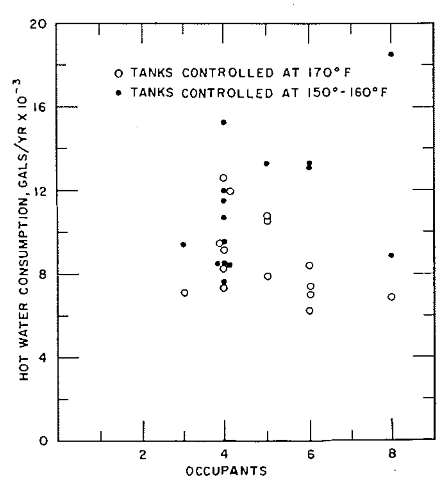

Figure 3—Rate of hot water consumption as related to number of occupants in the household. (Taken from Brantford, Belleville and Peterborough Projects)

TABLE 1—Details of Experimental Hot Water Systems in Windsor

Project Year	No. of Systems	Piping	Heater	Inhibitor
1948	5	galv.	3 kw side arm	none
1948	10	galv.	3 kw side arm	polyphosphate
1948	10	galv.	750 watt Immersion	polyphosphate
1949	5	copper	3 kw side arm	none
1949	10	copper	3 kw side arm	silicate
1949	10	copper	750 watt Immersion	silicate

There is some evidence that copper piping, even when stopped three feet from inlets and outlets of tanks, has some effect upon their corrosion in the Windsor area.

Although inhibitors were effective in prolonging life of galvanized tanks in Windsor heated by small immersion heaters, they were not nearly as effective in preventing corrosion as was the design change and the related change in service conditions. Thus, it is believed that much can be done to reduce corrosion of galvanized tanks by changing the system design and operating at the lowest temperature possible.

Metallographic examination of the corroded galvanized coating shows it is attacked irregularly as evidenced by horizontal and vertical cracks and fissures which often cause separation of zinc layers from the base, thus affording no protection at a time when much of its original volume remains. Because these fissures appear even in the uncorroded side of the tank they must be the result of faults produced during application of the galvanized coating.

It may be that corrosion begins at these faults. In any case it is evident that the protection this galvanizing layer offers to the steel is not what would be expected. These observations, therefore, indicate an area of fruitful future research.

Acknowledgment

The author thanks Central Mortgage and Housing Corporation for its complete cooperation in this project. Sample tanks were purchased and installed in their rental houses which the author was given permission to inspect at any time. The interest and assistance of I. E. Ashfield, Supervisor, Technical Department and of the regional supervisors of CMHC was most helpful. The interest and assistance of the Hydro-Electric Power Commission of Ontario and particularly of D. Watt also is here acknowledged with thanks. The author is grateful to his colleagues M. Cohen, who assisted in planning the project and in interpreting the results; to P. Beaubien, who prepared the micrographs and to H. F. Slade who made the physical inspections.

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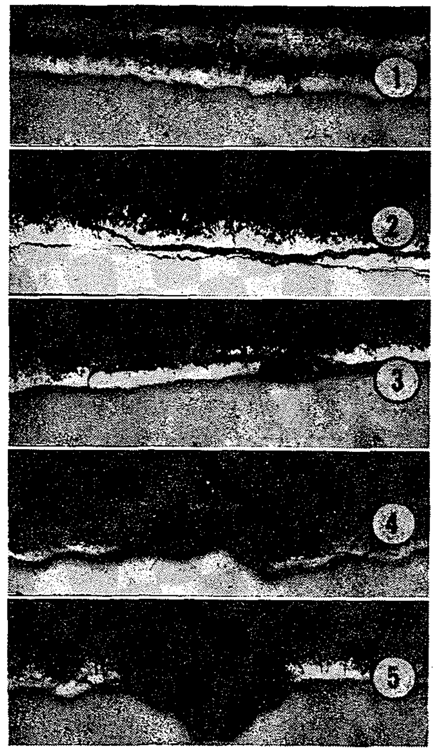

Figure 4—Micrographs from tanks removed from Brantford showing the characteristic corrosion attack on the galvanized coating. Magnification 96X. Number One shows an uncorroded edge. Numbers Two and Four are examples of a corroded edge from tanks operated at 170 F with failure after 3 years' service. Numbers Three and Four are of corroded edges from tanks operated at 150 F with failure after 6½ years' service. Number Five indicates a reversal of polarity.

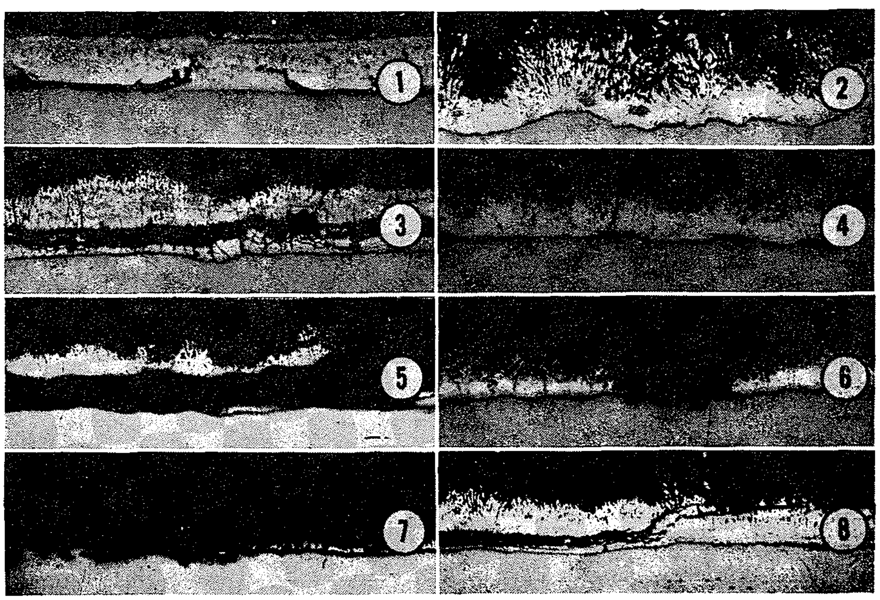

Figure 5—Micrographs of galvanized tanks removed from Windsor, Ontario. Number One is an uncorroded edge (96X). Number Two is a side arm heater with galvanized piping (161X). Numbers Three and Four are side arm heaters with copper piping, silicate inhibitor (161X). Numbers Five and Six are immersion heaters with copper piping, silicate inhibitor (96X and 161X respectively). Numbers Seven and Eight are immersion heaters with galvanized piping, phosphate inhibitor (161X).