CORRUGATED-MONEL EVAPORATOR BASKETS

MANUFACTURE, INSPECTION AND REPAIR

BY

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Introduction

The production of potable fresh water aboard a fighting ship is very necessary for the maintenance of operational efficiency. It is, therefore, essential that the evaporating equipment should operate without major breakdowns. To this end, the R.C.N. has fitted a modern type of evaporator system in all its recently built ships.

In this system the maintenance of scale-free evaporating surfaces is obtained by the use of flexible corrugated elements. These evaporating surfaces are constructed of monel metal in the form of fluted fingers, and the descaling of the basket is accomplished by flexing the flat sides of these fingers by building up a steam pressure of approximately 15 lb/sq in. inside the unit and then condensing the steam by dousing the outside of the basket with cold water; thus creating a vacuum inside, and flexing the basket fingers so that any scale which may have formed while producing the fresh water is cracked and broken off.

Prior to fitting this equipment into R.C.N. ships a prototype was assembled and was tested in H.M.C. Dockyard, Halifax, for three years. This prototype, set up under controlled and ideal conditions, operated without major troubles. However, when these evaporators came forward into service several problems occurred, and a major enquiry into their operational behaviour was initiated.

In September, 1957, while *en route* to the United Kingdom, H.M.C.S. *Assiniboine* was the first ship to suffer mechanical failure of an evaporator basket, after approximately 2,000 hours' evaporator service. Visual inspection by the ships staff revealed that approximately 70 per cent of the circumferential seam in the basket head was split, and a replacement unit was fitted at H.M. Dockyard, Portsmouth. It was suggested that this failure was due to over-pressurizing the unit. Therefore, all the heads of these evaporator baskets in service at that time were modified by the manufacturer. The original heads were flat, and were welded directly to the inner side of the fingers; these were replaced with a dished head welded in the same manner and position. This modification was only partially successful and reports of basket failures continued to be received from the Fleet at an alarming rate. It was soon apparent that these components were not standing up to the operational requirements, and that failure of the welded seams was all too frequent.

This article describes the work undertaken by H.M.C. Dockyard, Halifax, and the Naval Research Establishment—Dockyard Laboratory towards improving the service life of the corrugated baskets.

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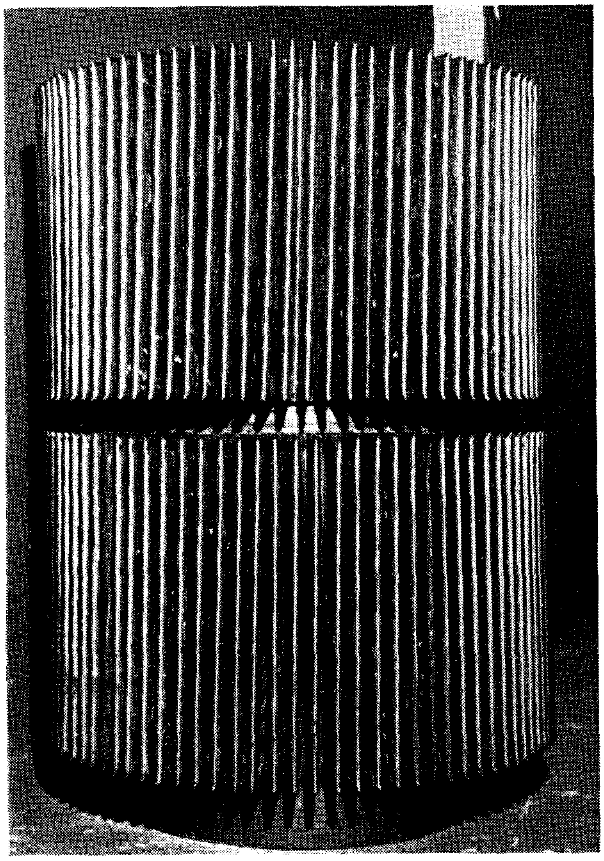

FIG. 1—MONEL EVAPORATOR BASKET

PRACTICAL TECHNOLOGY

Delineation of Faults in Manufacture

The first problem was to discover a suitable non-destructive testing technique which would reveal the reason for the failed seams and perhaps show the failures. Due to various factors it was decided that radiography was the only practical method inspection for these units. Although as can be seen from FIG. 1 the geometry of the basket was not ideal for this type of examination.

A limited success was achieved by the use of the double wall radiographic technique. However, further experiments showed that the most successful radiographic method was a single wall technique. In this method the X-ray head is placed at the appropriate distance and positioned so that the X-ray beam will be at right angles to the X-ray film which is placed inside the basket immediately behind the weld to be examined.

When using this method the X-ray film is approximately three inches away from the weld under investigation, making it necessary to increase the source to object distance to minimize the penumbra effect. When this method of radiographic inspection proved to be satisfactory, failed baskets could be examined in detail. The major defect found in the first casualty investigated was incomplete weld penetration at the weld root in all longitudinal fingers and dome seams, one of which had split in service. Other defects noted were heavy piping and porosity, but in this particular basket these defects were found only in the dome seam.

The split in the first unit was three inches long in one longitudinal finger seam running down the centre of the weld.

Due to the possibility that the serious defects as found in the first basket might lead to other premature failures, it was considered prudent to examine all spare units held by Naval Stores. This inspection showed that the condition of these spare units were no better than that of the failed baskets but as no other spare baskets were available at this time, there was no alternative but to exchange these known defective baskets for the failed units. These baskets remained a constant source of trouble until, as explained later, a technique was developed for their repair. Many other failed units have now been examined and in every case the failures have stemmed from incomplete penetration at the weldroots.

As destructive metallographic examination of the baskets is not feasible on a production basis, radiographic techniques were developed as the most practical method of controlling the quality of the welding.

To provide some estimation of the operational life of these units, radiographic inspection prior to fitting was recommended. To this end a specification was drawn up in conjunction with the R.C.N. and the manufacturer which was to apply to all future welded evaporator baskets.

The Cause and Repair of the Defects

The welding technique used on these seams necessitates welding from one side only: the outside. Failure to obtain full weld penetration results in a manufactured crack at the weld root, thus it is essential to eliminate this defect before satisfactory units can be obtained.

As a flexing operation is necessary to descale the evaporating surfaces, the importance of first class welding in all flexing seams is obvious. This is confirmed when it is found that the majority of the failures occur where incomplete penetration of the welds is found.

Investigation into the fabrication of these baskets showed that the main reason for the defect was the reluctance of the welder to apply sufficient heat to penetrate the parent plate during the welding of the seams. This was because of the danger, which was quite high, of burning through the thin material (0·050 monel) to the atmosphere, with resultant large holes, difficult to repair.

To enable the welder to increase his welding heat without the danger of burning through the monel metal, a copper backing bar with a groove, cut around the edge was designed. This bar was inserted behind the area to be welded, holes were drilled through this bar into the grooves, and the space behind the weld was flooded with argon gas while the welding operation was in progress. The fear of burning through the material into the atmosphere was thus reduced.

This technique proved successful, and welds free from the unacceptable defect of incomplete penetration were obtained. However, the contour of the inner bead left much to be desired, as the molten metal followed the contour of the backing bar groove, leaving a sharp edge running along the inner bead. As the experiments progressed it was obvious that this method required improvement and this is explained later.

It was reasonable to assume that other baskets would fail in service, considering the condition of the baskets examined, so the problem of repairing the defective baskets was studied. Two rejected baskets were allocated to the Naval Research Establishment—Dockyard Laboratory for use in the development of a suitable repair technique. To obtain a good base for the repairs it was necessary to cut the evaporating surfaces out of the whole component thus leaving only those surfaces for re-welding and/or rebuilding. The first problem was to find the quickest and best method of cutting the basket into two sections through the neck ring and so remove the inner ring and dished head.

A number of methods to section the baskets were tried, the most successful being a unit designed and built by the Boiler Shop under Manager Constructive Departments' direction. Using this tool a basket can be clamped in any position and with a portable power hack saw modified for the job, the baskets could be sectioned with the minimum loss of time due to dressing of damaged edges. (See FIG. 2.)

Once the baskets are sectioned and the rings removed visual examination of the corrugated sections was often sufficient to reveal incomplete penetration at the weld root.

To carry out local repairs to a particular seam takes considerable time, and once the section is prepared it takes only a little longer to re-weld the full seam. The same can be said for the complete basket, thus to eliminate any doubts which might exist regarding welds which had not been re-worked it was decided that all seams should be rewelded.

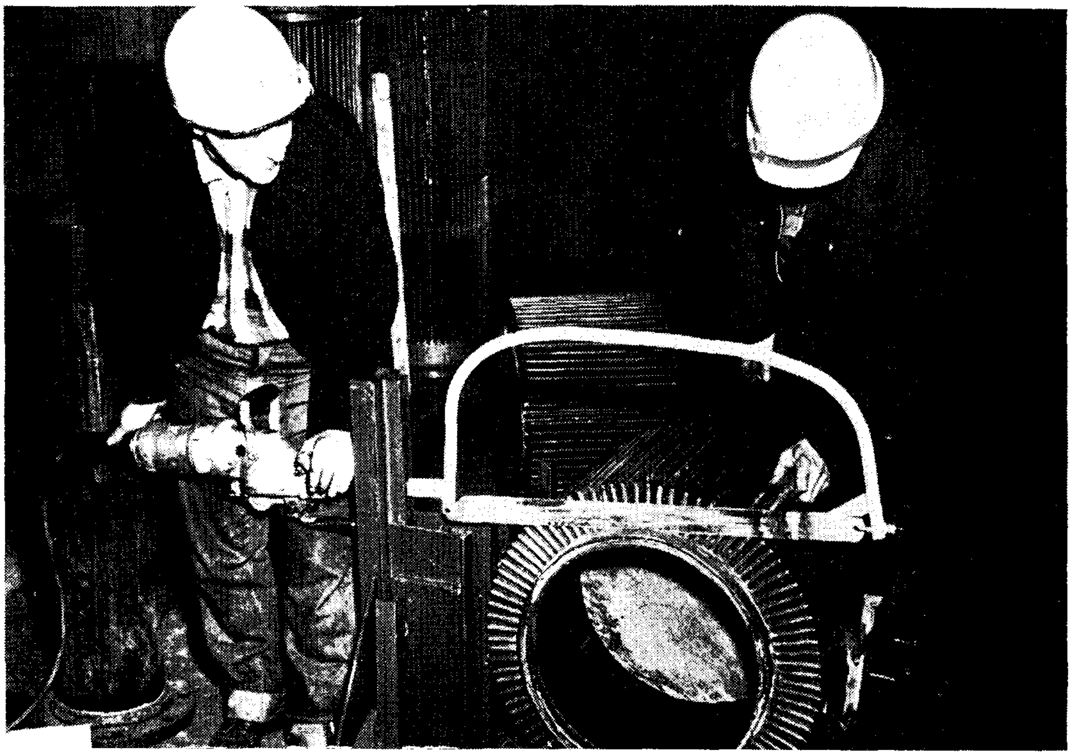

FIG. 2—POWER SAW AND HOLDING JIG

Pre-Weld Preparation and Welding Technique

In the areas to be repaired, any original excessive build-up of weld metal on the weld crown was first ground away leaving the weld metal flush with the parent plate. The remaining weld metal was then heated with the welding torch to run the metal completely through the parent plate to form the inner bead. On the second pass, Inco 60 monel filler wire was added to complete the weld crown.

Experiments showed that when old metal was used to form the inner bead no backing gas was required. But in any areas where new material was fitted, argon gas was necessary, as already explained, to shield the weld root. As the work proceeded, a modified backing bar, a perforated length of copper tubing $\frac{3}{16}$ in. diameter was developed. This gadget was easy to use and inexpensive to produce.

It was found that by using this type of backing bar it was possible to obtain an even distribution of the weld metal, without the danger of sharp edges forming on the inner bead. The finger seams were all welded with a Canadian liquid air model H10A manual heliweld torch, with a $\frac{3}{32}$ in. tungsten electrode and Inco 60 monel filler wire $\frac{1}{16}$ in. diameter; the optimum setting for this type of work on our machine was 45-50 amps, 15 volts.

Pressure Testing of Re-worked Sections

Each repaired section was pressure tested at 30 lb/sq in. If acceptable, the sections were then radiographed and, where necessary, defective welds were repaired and re-radiographed. The acceptable sections were then joined together with a new neck ring, welded with an Inco 130 monel electrode $\frac{1}{8}$ in. diameter using 95-100 amps at 20 volts. After joining the corrugated sections the completed unit was subjected to a further pressure test of 25 lb/sq in. for one hour.

The repaired baskets were then stress relieved in an oil-fired furnace at a temperature of 1,200 degrees F. for 30 minutes. The baskets were placed in the

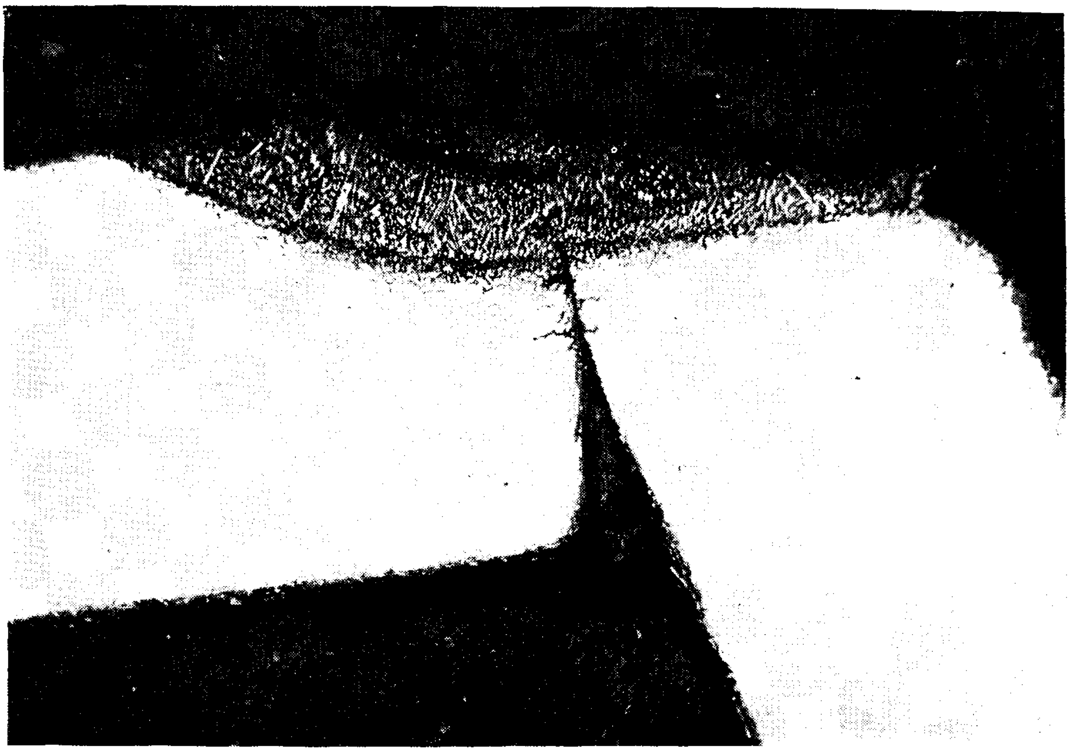

FIG. 3—UNACCEPTABLE WELD

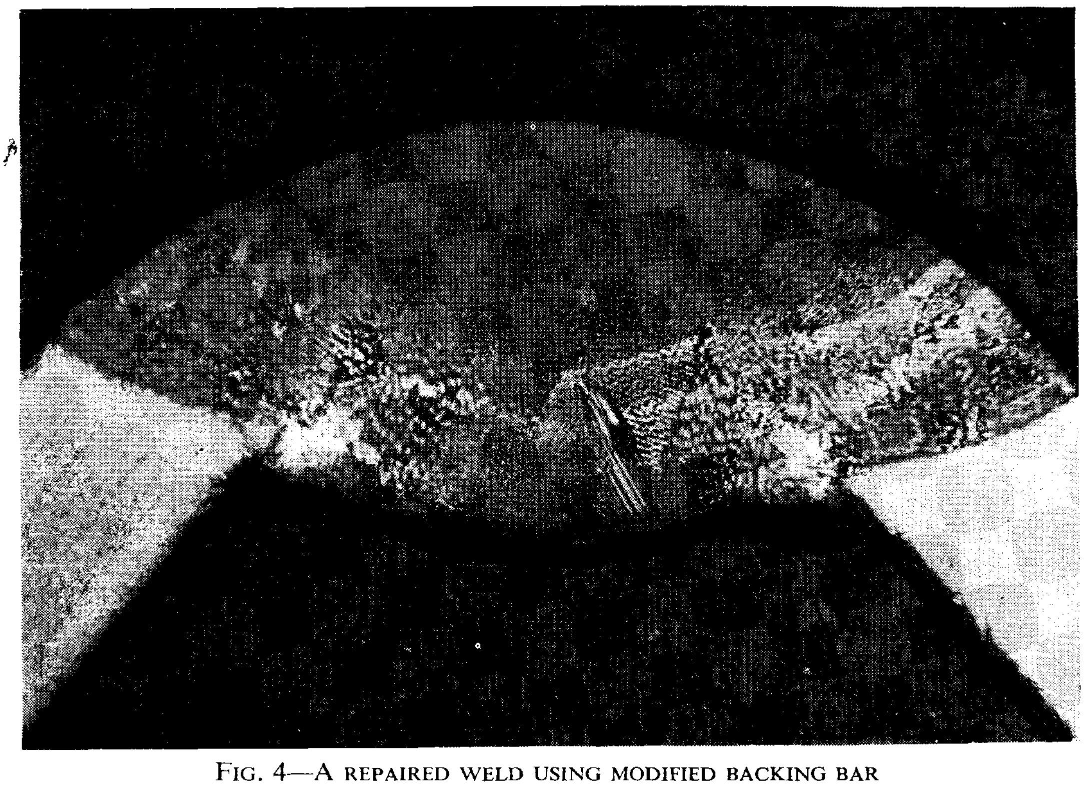

FIG. 4—A REPAIRED WELD USING MODIFIED BACKING BAR

cold furnace, and after stress-relieving they were permitted to cool in the furnace at no particular rate, but it took approximately 12 hours to cool one basket. Due to the possibility of sulphur embrittlement to which this alloy is prone, the sulphur content of the furnace oil was checked and was found to be within the acceptable limit (0·05 per cent).

The final test before these baskets were released for service was a shock test. Our method of shock testing was crude but effective. A steam pressure of 30 lb/sq in. was applied to the basket at approximately 250 degrees F., and when the required pressure and temperature were reached the unit was doused with cold water: this gave an approximate 26 inches vacuum. This procedure was repeated 12 times, equal to 1,500 operational hours.

The two repaired baskets were again put into service on May 2nd, 1960, and at the time of writing are still functioning satisfactorily.

As was stated earlier, because of logistical problems, many baskets with a very limited life expectancy were fitted in operational ships. On occasion, these baskets had to be repaired by the ships company while the ships were operational. This was usually done by silver soldering. On return to base such sections were inserted. These sections were formed by hand because no jigs were available to form the finger corrugation.

The original welding techniques appear to be satisfactory and are still being used. FIG. 3 shows an unacceptable weld before repair. FIG. 4 shows an example of a welded repair, using the modified backing bar.

CONCLUSIONS

Since successfully repairing the original two baskets in 1958, some 35 baskets have been completely rebuilt; these have now been in service for various periods up to 4 years, and to date, only one failure has been reported. The final test of the repairs described can be judged only by the length of operational service of these units. It is hoped that a minimum service life of six years will result but ten to twelve years should not be asking too much from a properly manufactured basket.

Looking back over the work described it would appear that the primary reason for the problem was lack of supervision and inspection at the manufacturer's works.

This opinion was accepted by the U.S. Naval Authorities who also experienced difficulties with these baskets and it is with some satisfaction the authors can report that the U.S.N. have based their own repair programme on the techniques developed at Naval Research Establishment—Dockyard Laboratory, and have demanded more rigid inspection of their baskets by the manufacturers. Further, they required a clause in their contract with the manufacturer, for radiographic control similar to that originally submitted by Naval Research Establishment—Dockyard Laboratory to the R.C.N.

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