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AN EXAMINATION OF STAINLESS STEEL MICROSTRAINER FABRICS SHOWING "PINHOLING" WHEN USED TO FILTER LAKE ERIE WATER

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Stainless steel microstrainer fabrics, showing "pinholes" when used to filter Lake Erie water, were examined. The evidence indicated that the pinholes resulted from crevice corrosion. The stainless steel was found to have a composition corresponding to Type 302. Examination of the microstructure suggested that the optimum annealing conditions had not always been reached and that consequently the ideal condition of the microstructure for corrosion resistance had not always been attained.

However, the "pinholing" could not be definitely related to metallurgical factors. It appeared more likely that the corrosion resulted primarily from the inherent corrosivity of the service environment.

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INTRODUCTION

On March 20, 1962, the Physical Metallurgy Division was informed that pinholes were developing in Mark O stainless steel microstrainers used by the Ontario Water Resources Commission (OWRC) at their Dunnville, Ontario, water filtration plant. It was not entirely clear whether the pinholing was due to corrosion or mechanical damage, although an investigation by Mr. T.H. Adair of the Ontario Research Foundation (ORF) had pointed strongly towards corrosion(1).

The writers visited Toronto on March 27 and April 5, and discussed the problem with representatives of OWRC, ORF, Glenfield and Kennedy Limited (manufacturers of the filters) and other organizations involved in the installation of the filters. The Dunnville filtration plant was also visited and the writers inspected the microstrainer units in operation(2,3).

Subsequent to these meetings there seemed to be general agreement that the pinholing was due primarily to corrosion, but the precise cause of the corrosion was uncertain. A leading possibility was that the water at Dunnville was particularly corrosive, due to precipitation of $CaCO_3$ at crevices in the filters, and subsequent crevice corrosion attack.

It also appeared possible that the metal used in the microstrainers might be defective in some way, either due to surface contamination during fabrication and installation, or due to departure from chemical and physical specifications. On behalf of the Physical Metallurgy Division, the writers agreed to examine a number of specimens of microstrainer fabric, both corroded and uncorroded, and report on their findings.

The following samples were obtained by the writers:

1. Six samples of used microstrainer fabric, about 12 in. x 8 in. in size, one sample being from each of the six microstrainer units at the Dunnville installation.

2. A sample of used microstrainer fabric, about 2 ft x 1½ ft, bolted to a much coarser backing screen, from the Dunnville installation.

3. Two small samples of unused microstrainer fabric.

4. A small sample of used Mark 1 microstrainer fabric from the Belleville, Ontario, installation.

5. A sample of used microstrainer fabric from No. 1 unit, Dunnville, Ontario, which showed a dark stripe of different colour from adjacent areas.

VISUAL EXAMINATION

(1) Specimens of Fabric from Each Microstrainer Unit

An arbitrarily chosen area of about 10 $in.^2$ was marked out on each of the six samples, and the pinholes were counted and examined, using a low-power stereomicroscope.

Many of the pinholes exhibited badly thinned wires, with no apparent distortion of the weave. Such pinholes were considered to be due to corrosion. Other pinholes were at cross-over points of wires on the coarse backing screen (which left a trace on the microstrainer fabric) and exhibited a definite distortion of the weave. It was considered that such pinholes were due primarily to mechanical damage, though there might have been subsequent corrosion.

The results of the examination, which appear in Table 1, indicated that 80% of the pinholes were due to corrosion.

TABLE 1

Pinhole Count on Samples of Fabric from the Six Microstrainer Units at Dunnville

Samples from Unit Number	Pinholes		
	Due to Corrosion	Due to Mechanical Damage	Total
1	4	0	4
2	7	2	9
3	5	0	5
4	0	0	0
5	1	1	2
6	13	3	16

In order to define the type of corrosion attack more clearly, it was decided to section some of the microstrainer fabrics in the vicinity of pinholes.

Figure 1 shows a typical pinhole of the type attributed to corrosion. It will be observed that the fabric weave is essentially undisturbed near the pinhole, despite the extent of attack which has occurred. It is also notable that many of the weft wires showed corrosion attack at points where they crossed over the warp wires (at the waist of the "dogbone" shapes). Figure 2 shows an example of this type of attack at a higher magnification.

(2) Sample of Microstrainer Fabric Attached to Backing Screen

A sample of a used microstrainer fabric taken from the Dunnville installation is shown in Figure 3. It is attached to its coarse backing screen by nut, bolt and washer assemblies. In Figure 4 an enlarged view of one of these assemblies is shown.

It was observed that the threads of many of the bolts were rusty. When the nuts were removed it was evident that this was due to crevice corrosion, occurring between the nut and a metal washer, and also in the crevice between the washers and the bolt heads.

It was observed that some of the pinholes were at cross-over points of the coarse backing screen and thus might have been initiated at this particular crevice, or by abrasion, due to relative motion of the two fabrics. However, other pinholes appeared at locations other than the cross-over points, and appeared to be due completely to corrosion.

(3) Samples of Unused Microstrainer Fabric

Two small samples of Mark O fabric, purportedly unused, were sectioned and examined. It was observed that corrosion appeared to be proceeding at some points where parallel weft wires were in contact (Figure 5).

(4) Sample of Used Microstrainer Fabric from Belleville

A small specimen of used Mark 1 microstrainer fabric, from the Belleville, Ontario water filtration installation, was examined using a low-power stereomicroscope.

Pinholes were observed that appeared to be due primarily to corrosion. The attack resembled that observed in the micro-strainer fabrics from the Dunnville installation. No sections were made through the fabrics from the Belleville installation.

(5) Sample of Microstrainer Fabric Showing Dark Streak

A small sample of microstrainer fabric from unit No. 1, Dunnville, was received[4] which showed a dark streak along the width of the panel. It was obvious that there were many more pinholes within the dark streak than in adjoining areas of normal colour. Microscopic examination showed that, within the streak, the weft wires had corroded to a greater extent than the warp wires.

Sections through the fabric, taken during the studies of microstructure, showed that the outer contours of weft wires within the streak were irregular, compared to similar wires outside the streak (Figures 8 and 9). This reflected the greater severity of the corrosion attack within the streak. A study of these figures also shows a difference in weave geometry, such that there were many more contact points between weft wires within the streak than without. There were thus many more points vulnerable to crevice attack.

CHEMICAL ANALYSES

Chemical analyses were conducted by gravimetric and spectrographic methods to determine the compositions of the microstrainer fabrics and the backing screen. These are shown in Table 2 with normal compositional ranges for stainless steel Types 302, 304 and 321.

The results of the analyses show that the microstrainers were made of material similar to AISI Type 302 stainless steel. The backing screen is similar to Type 321 stabilized stainless steel.

The elements shown by spectrographic analyses are mainly residual. The quantities of copper and molybdenum in microstrainer fabric #2 are higher than might have been anticipated.

MECHANICAL PROPERTIES

Hardness

An attempt was made to determine the hardness to show whether or not cold work remained in the wires. It was found to be impossible to polish sections mechanically without introducing cold work. This was confirmed by X-ray diffraction tests. Electrolytic polishing was not successful, due probably to the discontinuous surface presented by the microstrainer.

TABLE 2

Chemical Compositions (%)

	Type 321	Type 304	Type 302	Microstrainer Fabric #2	Microstrainer Fabric #4	Backing Screen
Gravimetric						
Carbon	0.08 max	0.08 max	0.15 max	0.13	0.18	0.14
Manganese	2.00 max	2.00 max	2.00 max	1.64	-	1.91
Chromium	17-19	18-20	17-19	18.60	18.60	17.70
Nickel	9-12	8-12	8-10	9.71	9.80	8.72
Titanium	5xC min			Residual	Residual	0.50
*Spectrographic						
Aluminum	-	-	-	0.06	0.07	0.42
Cobalt	-	-	-	0.13	0.09	0.14
Copper	-	-	-	0.18	0.10	0.16
Silicon	1.00 max	1.00 max	1.00 max	1.40	1.40	0.90
Vanadium	-	-	-	0.05	0.04	0.05
Molybdenum	-	-	-	**0.22	**0.09	0.28

*The spectrographic analyses are indicative of actual quantities present but do not provide as great a degree of accuracy as gravimetric analyses.

**Checked gravimetrically.

Consequently, it was concluded from the X-ray diffraction tests that the hardness would be similar to a fully-annealed hardness for this material. This would be within the range 140 to 160 Brinell (77 to 83 Rockwell B Scale). Hardness values of approximately 35 Rockwell C scale (converted from Knoop hardnesses) were obtained after polishing, and cold work in evidence in examples of microstructures is attributed to the polishing operation.

METALLOGRAPHIC EXAMINATION

Several sections of microstrainers were examined microscopically for evidence of corrosion and for metallurgical characteristics. Some examples of microstructures are shown in Figures 6 to 9. These include microstrainer numbers 1, 2 and 4, each number representing the respective unit at the Dunnville plant from which the fabric was removed. An unused section of microstrainer fabric was also examined.

In general, the examinations showed an austenitic matrix with evidence of work hardening (presumably from manual polishing of such small wires), and numerous small carbides in some specimens (for example, the warp wires of #2 microstrainer).

A dark streak in microstrainer #1 did not show any distinctive microstructural differences from adjacent areas of normal colour. However, there was some difficulty in obtaining uniform etches.

As noted previously, it was observed that the outer contours of the weft wires within the dark streak were less uniform than those outside that area (Figures 8 and 9).

The units (nuts, bolts and washers) used to bolt the microstrainers to the backing screen were not given detailed metallographic examinations. However, a brief examination of a polished section of the thread from a corroded nut revealed that it was a free machining (i.e. high sulphur) type of stainless steel, probably similar to AISI Type 303. Corrosion attack had progressed actively along the sulphide inclusions normally found in this type of steel. The corrosion resistance of free machining stainless steel is much less than that of non-sulphurized types.

CONCLUSIONS

The observations confirmed previous findings that the pinholing of the microstrainer fabrics was due primarily to corrosion, and that mechanical damage was a secondary factor. In many cases, corrosion was observed at crevices between adjacent wires. It is known that such corrosion, once started, can become self-propagating, and spread to areas in contact with fresh aerated water. It therefore appears likely that many of the pinholes resulted from original attack at a crevice or crevices.

The observations of increased corrosion within a dark streak on a microstrainer fabric are inconclusive, but they do suggest that further examinations should be carried out to determine whether such streaks are an important source of pinholing. If they are, an effort could be made to determine the manufacturing process variables which produce the streaks, with the object of eliminating them.

The observation of crevice attack on an unused microstrainer fabric cannot be considered conclusive, as the history of this fabric is not definitely established. However, it does suggest that greater attention could be paid to the condition of the microstrainer fabrics at the time of installation. Sectioning techniques such as those used in the present work would show whether or not corrosion had already begun.

The metallurgical examination did not produce any positive evidence of the specific cause of the corrosion observed in the microstrainers. However, there was evidence that optimum annealing conditions were not attained at all times. Although residual cold work did not exist, according to X-ray diffraction measurements, the large number of carbide particles in some of the wires indicated that time, temperature and possibly cooling rates, were not best suited to take carbides into solution and retain them. It has been widely accepted that stainless steels of this type provide the best resistance to corrosive attack when fully quench-annealed with absence of cold work and with most of the carbides retained in solution. Microstrainer numbers 2 and 4 were selected for examination since, for the sections examined, number 2 appeared to be much more severely pinholed than number 4. It is possibly worth noting that more carbides are apparent in microstrainer number 2 than in number 4.

On the whole, however, it appeared that the widespread crevice corrosion resulted from the inherent corrosivity of the service conditions, rather than from any specific metallurgical deficiency of the steel used in the microstrainers.

ACKNOWLEDGEMENTS

The chemical and spectrographic analyses were provided by the Mineral Sciences Division of the Mines Branch. The X-ray diffraction studies were carried out by the Metal Physics Section of the Physical Metallurgy Division.

REFERENCES

1. T.H. Adair - "Examination of Corroded Microstrainer Fabric" - Report of Investigation No. M-6226, Ontario Research Foundation, Toronto, Ontario (March 12, 1962).

2. R.D. McDonald and G.J. Biefer - "Visit to Toronto and Dunnville, Ontario, March 27, 1962 in connection with the appearance of pinholes in a new type of stainless steel filter in water filtration plants" - Internal Report PM-V-62-10, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa (April 18, 1962).

3. G.J. Biefer and R.D. McDonald - "Visit to Toronto, Ontario, April 5, 1962 to discuss the corrosion of stainless steel microfilters with Ontario Water Resources Commission"- Internal Report PM-V-62-11, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa (April 24, 1962).

4. K. Shikaze - Purification Process Branch, Ontario Water Resources Commission - Letter to G.J. Biefer (April 11, 1962).

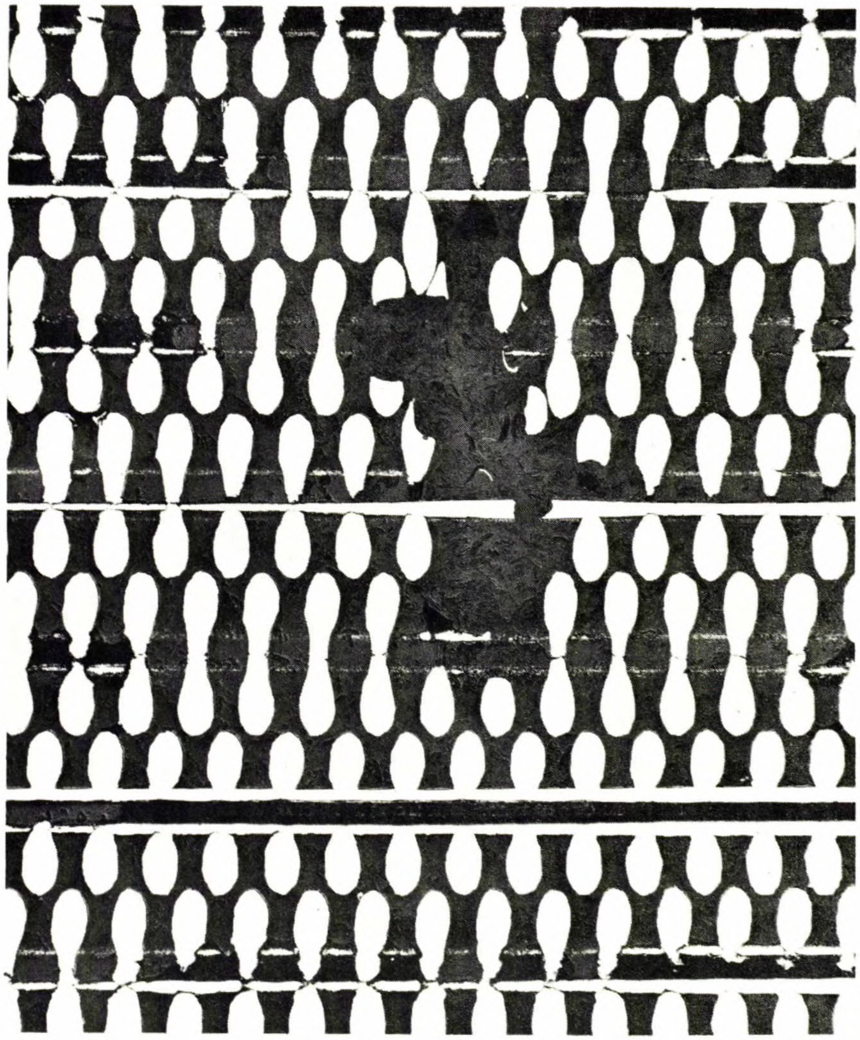

Figure 1. Section in plane of microstrainer fabric (Unit #2, Dunnville, Ontario), showing a pinhole. The pairs of wires lying horizontally represent the warp, while the "dogbone" shapes represent weft wires, which loop over and under pairs of warp wires. X100

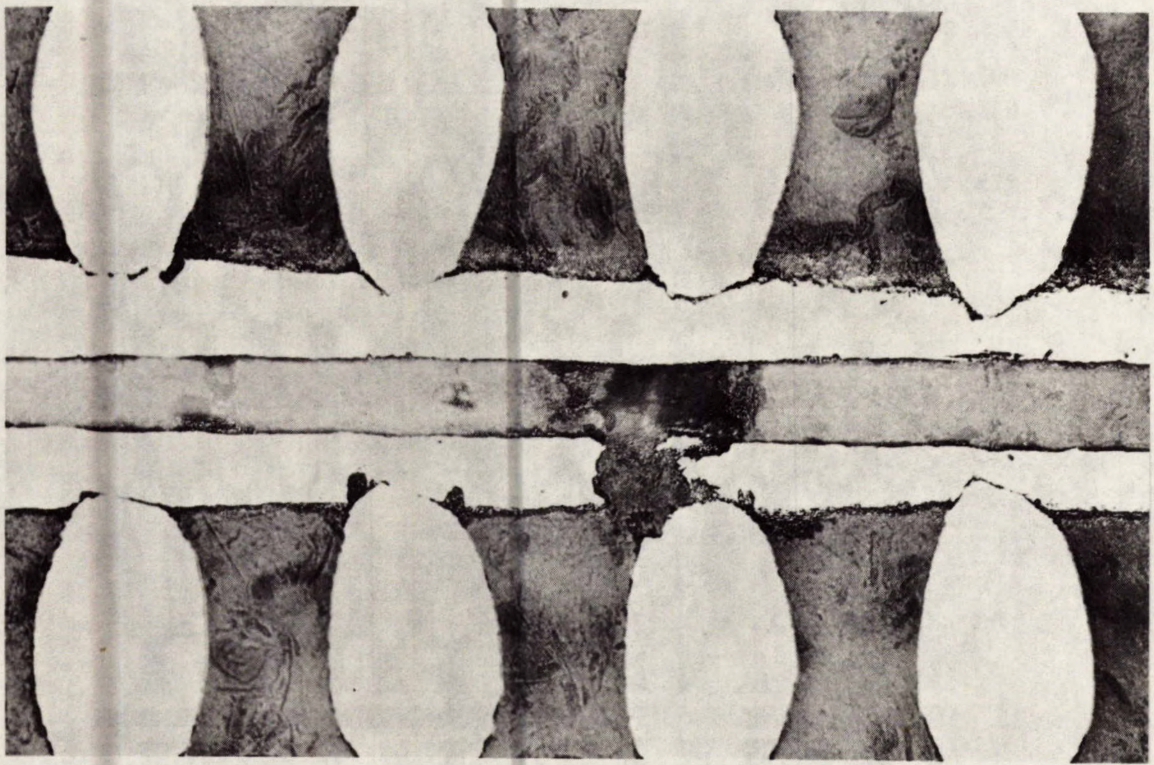

Figure 2. Section in plane of microstrainer fabric (Unit #4, Dunnville, Ontario), showing corrosion attack at cross-over points of warp and weft wires. One of the warp wires has been severed by the corrosion attack, which appears to be proceeding along the severed ends.

X500

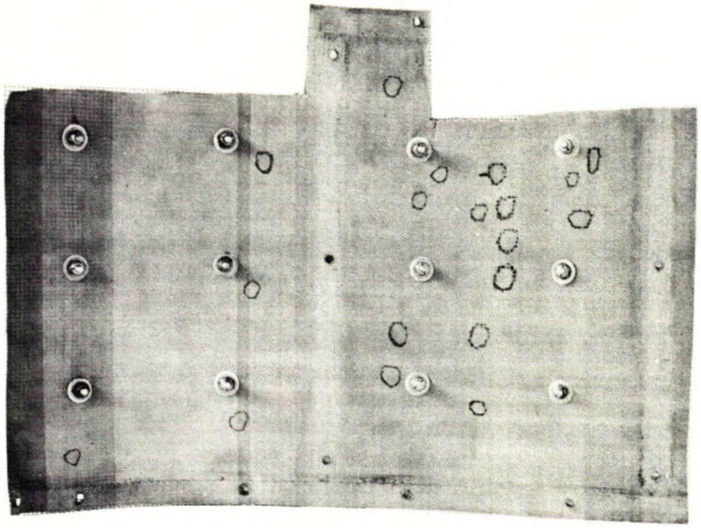

Figure 3. Microstrainer fabric, bolted to coarse backing screen. Some of the pinholes have been circled.
Approximately X 1/5

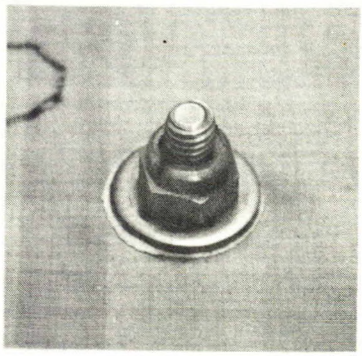

Figure 4. Nut and bolt assembly fastening microstrainer fabric to backing screen, showing rust on threads and in the crevice between metal washer and nut. Approximately X 1 1/2

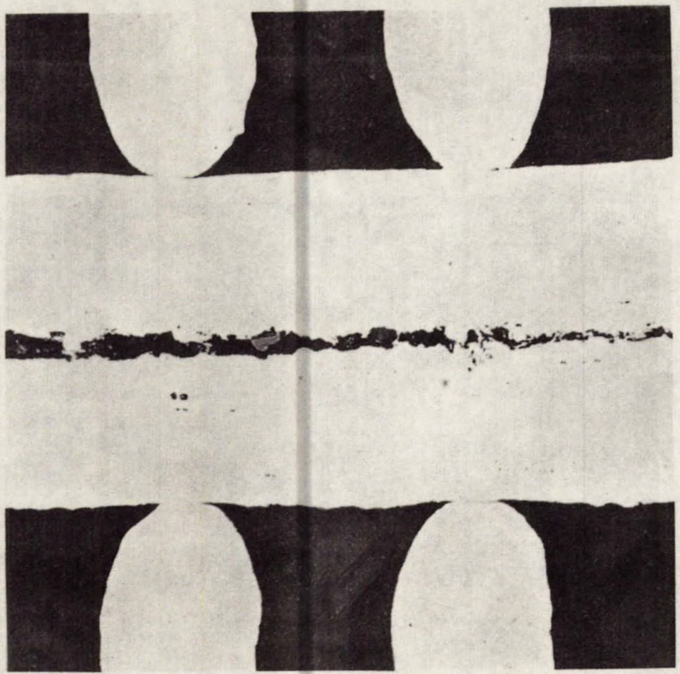

Figure 5. Section in plane of unused Mark 0 microstrainer, showing corrosion attack at contact point of two warp wires. X500

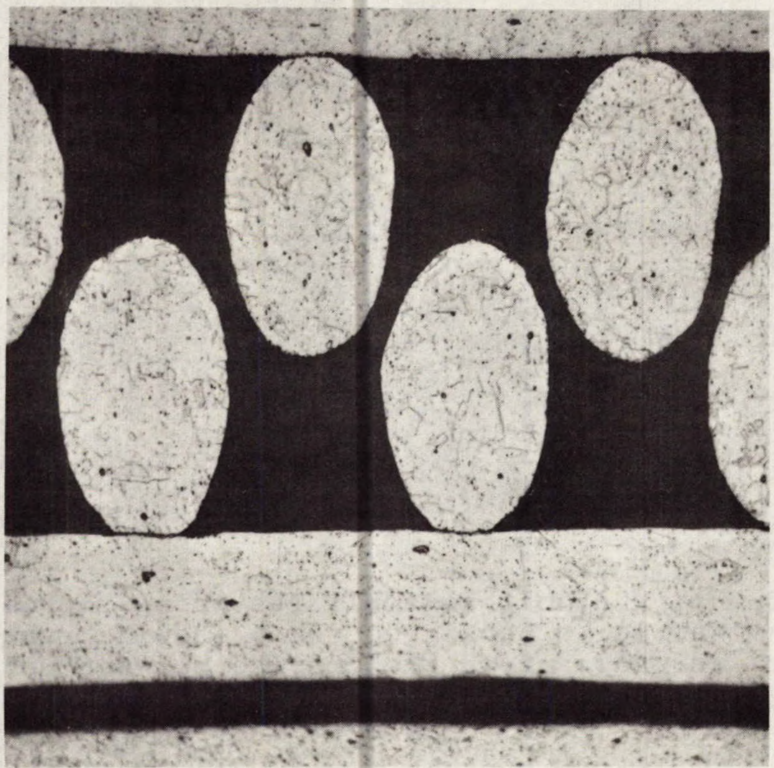

Figure 6. Microstructure of microstrainer fabric No. 2, showing austenite grain boundaries and large numbers of carbides in both warps and wefts. (Etched in Vilella's reagent, X500)

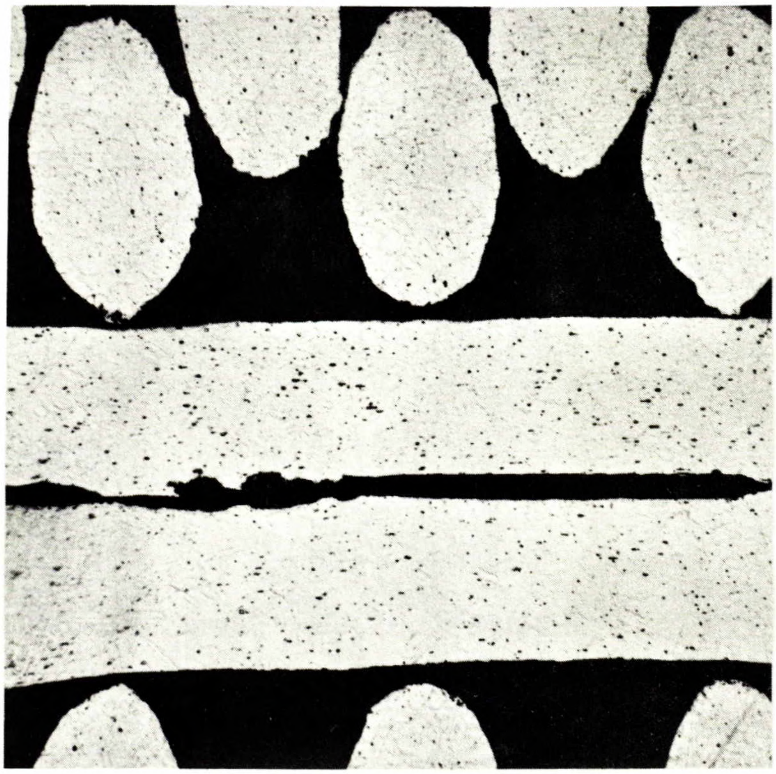

Figure 7. Microstructure of microstrainer fabric No. 4, showing austenite grains and carbides. The latter appear to be generally larger and fewer in number than those in No. 2 microstrainer. (Etched in Vilella's reagent, X500)

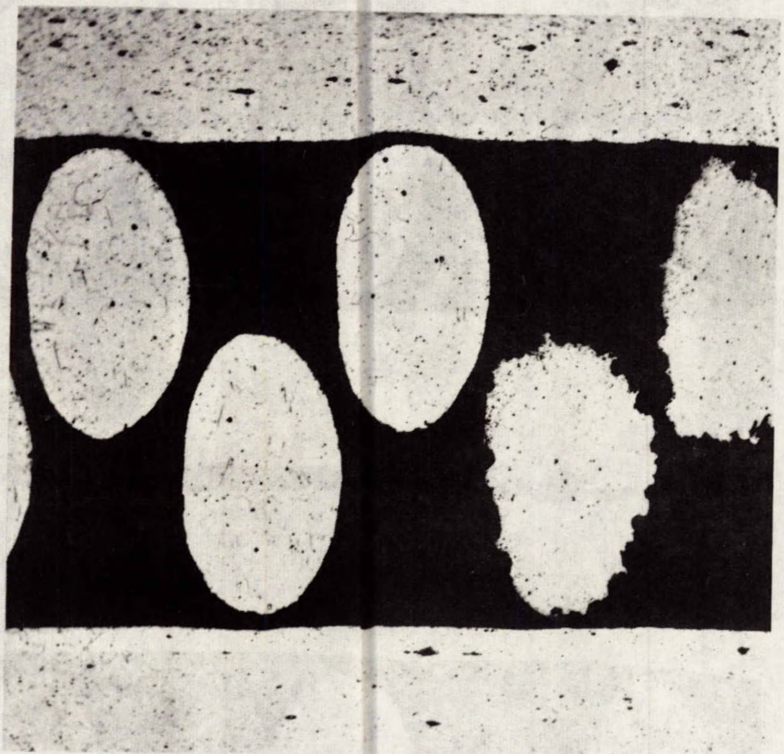

Figure 8. The weft wires on the right are within the dark streak on microstrainer No. 1. Those on the left are outside of it.
(Etched in Vilella's reagent, X500)

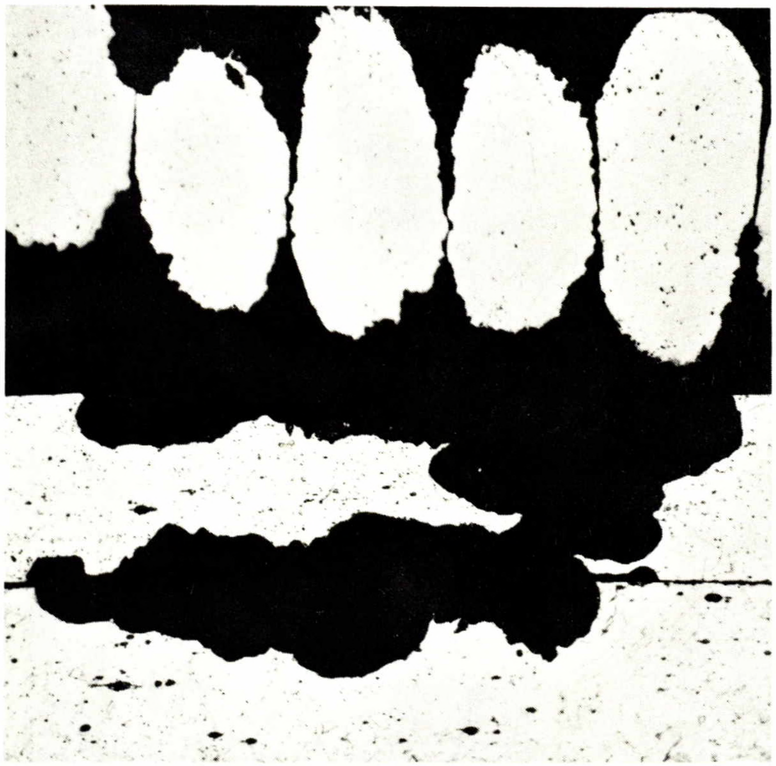

Figure 9. Corroded area within the dark streak (microstrainer No. 1), showing crevice attack in warp wires and around the periphery of the weft wires. (Etched in Vilella's reagent, X500)