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METALLURGICAL EXAMINATION OF A STAINLESS STEEL IMPELLER WHICH FAILED IN SERVICE

by

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SUMMARY

Examination of a cast-welded stainless steel impeller, which had failed in service while pumping sea water, did not disclose any metallurgical defect which could account for the failure.

The composition of the material which failed was found to conform to the specification for ACI CF-8M (cast equivalent of wrought AISI Type 316). Fracture occurred in a brittle manner, along a trans-crystalline path, apparently over an extended period of time.

Hardness testing of the as-received impeller and of portions of the impeller, given a quench-anneal, confirmed that the impeller had been fabricated from quench-annealed material.

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(6 pages, 2 tables, 4 illus.)

INTRODUCTION

Under a covering letter of March 25, 1958, Mr. C.W. Farrar, Chief Metallurgist of Fahralloy (Canada) Limited, Orillia, Ontario, forwarded a stainless steel impeller for metallurgical examination. It was stated that this impeller was one of four type 316 stainless steel impellers which had failed in the same manner. The following quotations are from the covering letter:

> "These impellers operate without vibration or shock loads in pairs with one under continual operation at constant load and the other operating for approximately one hour every 6 to 8 hours. The liquid pumped is sea water which has been well strained and is free from debris of any kind.
>
> "The first impeller failure occurred after two to three months, the second in three to four months and another after only one month."
>
> "Customer says 'the brinell hardness should be 156-170 whereas the actual casting shows a brinell of 186 on the unmachined castings and 192 on the finished surface. It would appear, therefore, that the castings received were not properly annealed'."
>
> "Our brinells show 156. Examination shows that cracks started at the edge and ran into the plug weld and then proceeded to another weld."
>
> "The castings are fabricated from three castings by drilling holes at points indicated on the impeller and then plug welded."

MACROEXAMINATION

The failed impeller is shown in Figures 1 and 2*. Visual examination indicated that each of the failures initiated at the periphery near a plug weld. The path of each fracture then progressed in a brittle fashion and in a direction counter to the rotation of the impeller through a second plug weld and advanced almost to a third

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*All figures are appended.

plug weld near the periphery. The last portion of each fracture was ductile.

The inner surfaces of the impeller and the brittle portion of the fractures were coated with a thin, light-brown deposit.

The brittle portions of the fracture surfaces appeared to have been abraded, indicating that the failure had progressed over a period of time during which the mating surfaces had flexed and worn against each other. The only evidence of ductility in the brittle portion of the fracture was a very thin shear lip, about $6\frac{1}{4}$ in. deep, along the outer edge. No shear lip was present along the inner edge.

RADIOGRAPHY

Radiography showed that the impeller contains regions of microshrinkage and numerous round voids. However, none of these defects appeared to be associated with the fracture or with the path of the fracture. The white arrow in Figures 1 and 2 points to a region of microshrinkage at the periphery.

COMPOSITION

The composition of the fractured side was found to conform to CF-8M and the unfractured side was found to conform to CF-20 specifications of the Alloy Castings Institute. The composition of each side and the corresponding specifications, in weight percent, are given in Table I.

TABLE I

Composition of Each Side of the Impeller
Along With Relevant ACI Specifications

Element	Fractured Side	CF-8M	Unfractured Side	CF-20
Carbon	.08	.08 max	.14	.20 max
Manganese	.64	1.5 max	.62	1.5 max
Silicon	1.45	2.0 max	1.21	2.0 max
Sulphur	.020	.05 max	.022	.05 max
Phosphorus	.028	.05 max	.029	.05 max
Nickel	9.56	9.0/12.0	9.54	8.0/11.0
Chromium	20.23	18.0/21.0	20.41	18.0/21.0
Molybdenum	2.42	2.0/3.0	.28	-

HARDNESS

Average Brinell hardness readings, both as-received and after quench annealing, are shown in Table II.

TABLE II

Average Brinell Hardness Values

	Fractured Side	Unfractured Side
As-received (machined surface)	190	159
Quench-annealed	183	156

MAGNETIC CHARACTERISTICS

A hand-held magnet was strongly attracted to the fractured side but only weakly attracted to the unfractured side of the impeller.

Use of an Aminco-Brenner Magne-Gage indicated that the fractured side contains about 4% ferrite, whereas the unfractured side contains about 2½% ferrite.

MICROSCOPIC EXAMINATION

The microstructure of both sides of the impeller including

the weld deposit, consists essentially of a matrix of austenite with pools of ferrite. No sigma phase was detected. No microstructural defects were observed in the vicinity of the failures.

The path of the brittle portion of the failure was transcrytalline.

No evidence of corrosion of the impeller was observed.

Microshrinkage observed in the areas shown, by an arrow, in Figures 1 and 2 is shown in Figures 3 and 4.

CONCLUSIONS

1. Both sides of the impeller were in the quench-annealed condition while in service.

2. The average hardness of the fractured side was Brinell 190, whereas the average hardness of the unfractured side was Brinell 156.

3. The failure was of a brittle nature. However, the fracture apparently progressed slowly.

4. The path of brittle fracture was transcrystalline.

5. There were no metallurgical defects in the immediate vicinity of the failures.

6. The composition of the fractured side conforms to ACI CF-8M (cast equivalent of wrought AISI Type 316). The composition of the unfractured side conforms to ACI CF-20 specification.

7. Visual examination of the fracture path suggests that failure was related in some manner to the plug welds. Since the microstructure in the welds and near the welds was satisfactory it may be that failure was associated with residual stresses induced by welding.

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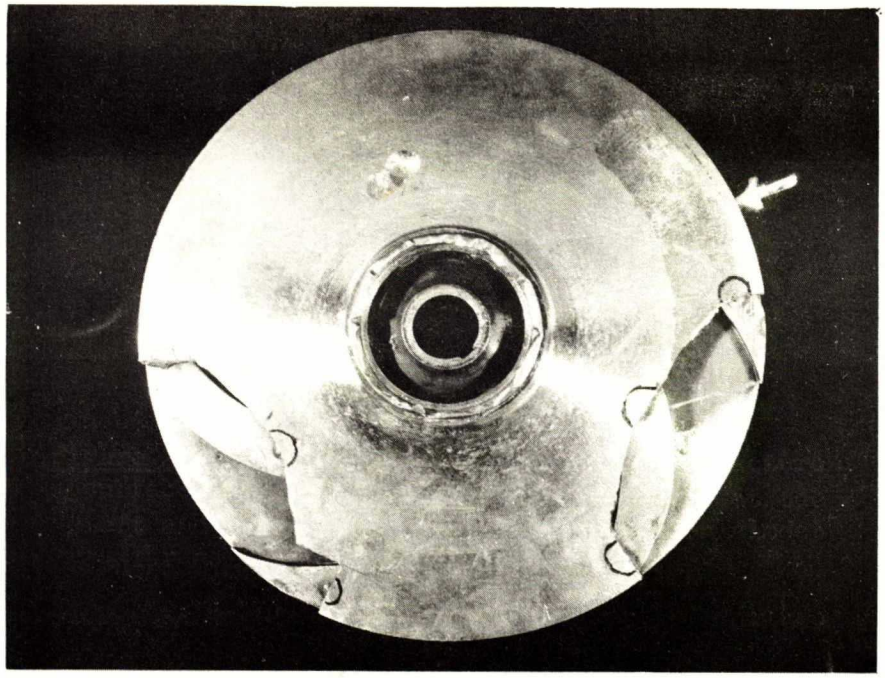

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Figure 1. - Plan view of impeller, showing location of the failures. The black semi-circles denote the plug-welded areas.

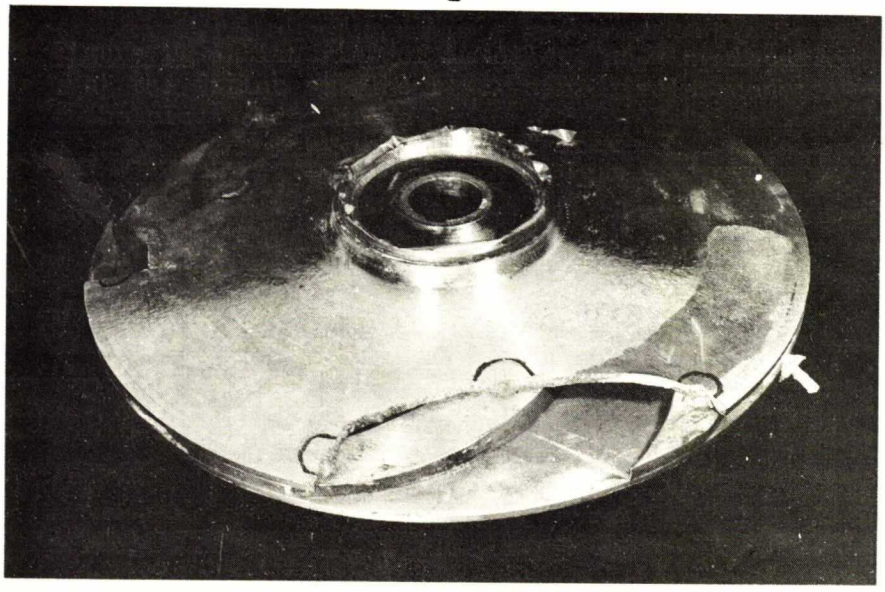

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Figure 2. - Angle close-up of one of the fracture surfaces. Failure apparently originated at the left and progressed in a brittle fashion almost as far as the plug weld on the right.

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Figure 3. - Microshrinkage extending to outer edge of the impeller at the right.

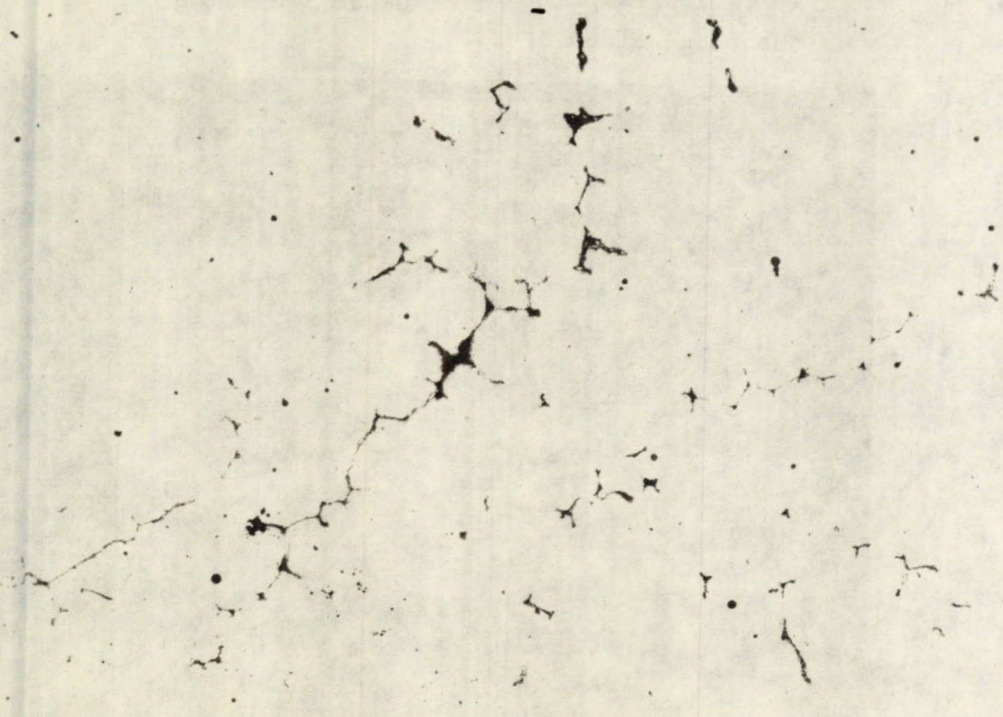

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Figure 4. - Enlargement of an area from or near the field shown in Figure 3.

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