NATIONAL BUREAU OF STANDARDS REPORT

9642

Howell-Bunger Valve No. 1
Summersville Dam, Gauley River,
West Virginia

By

T. R. Shives
Engineering Metallurgy Section
Metallurgy Division

Submitted by

Department of the Army
Huntington District, Corps of Engineers
Huntington, West Virginia

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D. C., 20234.

[2] Located at Boulder, Colorado, 80302.

[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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NBS PROJECT

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FORM NBS-259
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U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

NATIONAL BUREAU OF STANDARDS

REPORT OF TEST

Howell-Bunger Valve No. 1, Summersville Dam, Gauley River, West Virginia

Submitted by

Department of the Army
Huntington District, Corps of Engineers
Huntington, West Virginia

Reference: Letter dated July 21, 1967 from S. F. Brown, Asst. Chief Engineering Division, Huntington District, Corps of Engineers, Department of the Army, ORHED-DE.

The reference requested that:

(a). Chemical analysis, tensile tests, and bend tests be conducted on the vane steel in accordance with ASTM specification A 373-58T for structural welding steel.

(b). Cause of failure be determined.

Background Information:

On August 3, 1967, T. R. Shives of the National Bureau of Standards met with Mr. Jacob Herman of the Huntington District, Corps of Engineers, at the site of the failed valve at Summersville, West Virginia, to examine the failure. Four of the six vanes of the valve had fractured both at the valve hub and at the valve outer shell, these vanes being in positions 6, 8, 10 and 12. Only vanes in positions 2 and 4 were intact. The vanes are numbered in a clockwise manner facing downstream, with the numbers corresponding to the hours on a clock face. The fractured surfaces had been exposed to water flow for an undetermined period of time and their erroded and corroded condition made it impossible to ascertain at the site the nature and cause of failure.

A portion of the upstream end of the valve consisting of part of the hub (approximately 18 inches in length) and parts of both remaining vanes was designated to be cut out and shipped to NBS for examination (figure 1).

Specification Tests:

Material for tests in accordance with ASTM specification A 373-58T was taken from vane 2.

a) Chemical Analysis

The Microchemical Analysis Section of NBS performed the chemical analysis and obtained the following results:

Element	Percent by Weight
Carbon	0.23
Manganese	0.86
Phosphorus	0.014
Sulfur	0.023
Silicon	$<$ 0.05
Copper	0.06

This steel thus meets the requirements of ASTM specification A 373-58T for chemical composition.

b) Bend Tests

Two bend specimens of the one inch thick steel vane were made. The specimens were 1 1/2 inches wide and 9 5/8 inches long. They were bent 180° over a one inch diameter mandrel and both performed in a satisfactory manner. The outer surfaces of the specimens were examined for cracks with a die penetrant technique and none were found.

c) Tensile Tests

Three tensile tests were conducted on specimens with an eight inch gage length and a diameter of 0.350 inch in the reduced area. From these tests, ultimate tensile strength, yield strength, and percent elongation were determined as shown below. Tensile and yield strength values are rounded to the nearest 100 psi and elongation to the nearest one-half percent.

Speci-men	Tensile Strength, psi	Yield Strength 0.2% offset, psi	Elongation % in 8 in.
T-1	66,000	34,600	19.0
T-2	65,700	35,000	20.5
T-3	64,600	34,200	20.0

All three specimens met ASTM specification A 373-58T for tensile and yield strength. The specification calls for a minimum elongation of 20 percent (corrected for a plate thickness of one inch) in eight inches. One specimen barely failed to meet specifications, having one percent less elongation than acceptable.

Fracture Examination:

A transverse slice through the hub and parts of each vane about 12 inches from the upstream end of the valve is shown in figure 2. This section has been etched to show the configuration of the weld material and heat affected zones in relation to the hub and vanes. Most of vanes 2 and 4 have been cut off. Each of the fractures began in the region where the weld material meets the heat affected zone of the vane.

In addition to the four fractured vanes, a crack about five inches long was found in the upstream end of vane 4 in the same relative location as the other fractures (figure 3). The crack was opened and the exposed fracture surface is shown in figures 4 and 5. The fracture consists of two series of cracks, each of which has many sources, which propagated in fatigue. One series originated on either side of the vane and propagated transversely (in figures 4 and 5, one series propagated upward and one downward) toward the center of the vane. The junction of the two series is characterized by the longitudinal ridge near the fracture center.

The exact starting points of the cracks could not be determined from the fracture surface, but the most probable locations are at "a" and "b" (figure 4) because the cyclic stress due to bending of the vane would have been greatest there.

On some of the transverse ridges, striations are visible (not clearly evident in the photographs). The spacing of these striations indicates that the fatigue cracks were probably propagating at a fairly high rate, which in turn indicates that the cyclic stress was much higher than the fatigue limit of this material.

It is to be noted from figure 2 that there are somewhat sharp re-entrant angles at the junction between weld material and the heat affected zone in the segments of the two vanes which had not failed. These re-entrant angles act as notches or stress concentrators which are very undesirable and can be quite detrimental. The crack in vane 4 occurred at such a place, and while it is difficult to establish the severity of the angle between the weld and vane for the four fractured vanes, the fractures occurred in the regions of these angles. It is quite likely that the same undesirable re-entrant angles existed for these vanes also.

This condition can be corrected by grinding these angles to provide a smooth transition from the weld to the vane. The failure would definitely be postponed by the elimination of these re-entrant angles, but there is no assurance, however, that eventual failure in these areas would not occur. The cyclic stresses are quite high, as mentioned earlier, and this investigator is not aware of any valve assembly in operation with the re-entrant angles ground smooth so that a comparison can be made.

Microstructure:

The microstructure of the hub (figure 6) consists primarily of ferrite and pearlite with a reasonably fine grain size. This structure is considered to be satisfactory.

In some areas between the hub and the vanes where there is a lack of welding (figure 2), the surface of the hub exhibits some decarburization (figure 7) which would tend to weaken the material, but this has not contributed to the failure.

Vane 4, which had partially fractured, exhibits some evidence of an undesirable Widmannstätten structure (figure 8). The microstructure of fractured vane 6 (figure 9) is coarse and exhibits a Widmannstätten structure to a greater degree. Prior austenite grains are visible. The structure of vane 6 is poorer than that of vane 4, but both structures indicate too high a rolling temperature for the steel.

The microstructures of the weld material and the associated heat affected zones (figures 10 and 11) are satisfactory.

Knoop microhardness measurements with a 500 gram load were made on the section shown in figure 2 in the hub, in the portions of vanes 4 and 6, in weld material and in various areas of the heat affected zone. In addition, hardness measurements were made adjacent to the fracture in vane 6. All hardness results are considered satisfactory. Hardness in the weld material ranged from a Knoop hardness of 142 (equivalent to approximately 71.5 Rockwell B) to 244 (approximately 99 Rockwell B), but this is not unusual. The other constitutents yielded fairly consistent values. Averages are given below.

Material	KHN (500 gram load)	Approx. R_B Equivalent
Hub	159	78
Vane 4	141	71
Vane 6	149	74
Heat affected zone	156	79

Stress Relief Treatment:

It could not be determined from the appearance of the microstructure or the measured hardness values whether an adequate stress relieving treatment had been applied.

Summary and Conclusions:

1. The mode of fracture in this valve assembly is fatigue, the cyclic stressing being caused by the flowing water vibrating the vanes. The fracture surface indicates that the stress amplitude was greater than the fatigue limit for the material employed.

2. Probably the most detrimental condition in the valve assembly is the occurrence of re-entrant angles where the weld material meets the vanes. These act as stress concentrators and should be ground to make a smooth transition from weld to vane. The fractures started at these regions between the weld and the heat affected zone of the vanes.

3. The vane steel meets ASTM specification A 373-58T for chemical composition, bending ductility, tensile strength, and yield strength.

4. The elongation of one specimen of the vane steel was slightly less than that called for in ASTM specification A 373-58T.

5. The microstructures of the hub, welds, and associated heat affected zones are satisfactory.

6. The microstructure of the vanes is undesirable and indicates that the temperature of rolling was too high.

Comments:

Correcting the undesirable conditions found in this valve assembly would definitely postpone failure, but not necessarily preclude it. The fracture surfaces indicate that the vanes were subjected to a high cyclic stress caused by the flowing water. Since we cannot compare the results obtained from this valve with those from a valve in which the objectionable conditions had been eliminated, there is no assurance that in a corrected valve the stresses would not exceed the fatigue limit for this material.

It is the opinion of this investigator that it would be wise to reconsider the design of the valve with the intention of producing a more rigid structure.

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Figure 1. Portion of Howell-Bunger Valve No. 1 as received at NBS. Vane numbers are shown. X 1/4

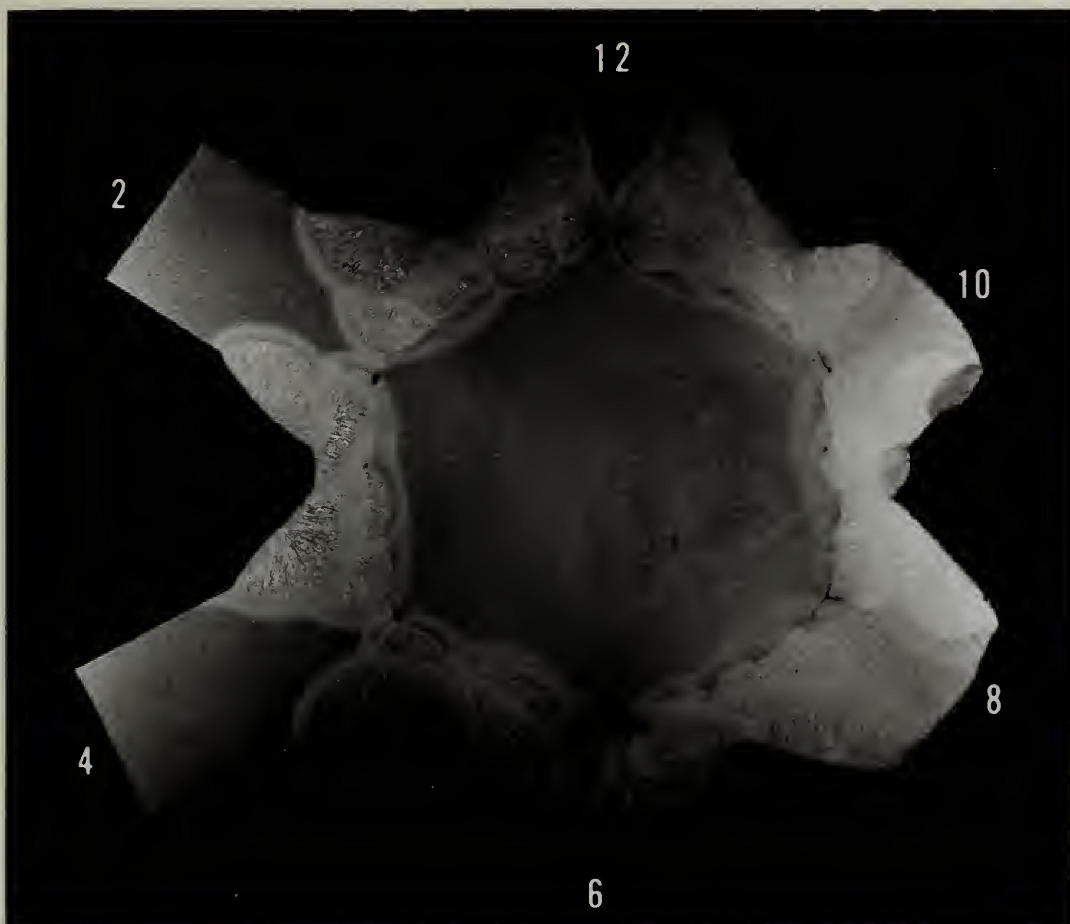

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Figure 2. Transverse slice through hub and part of each vane. Vane numbers are shown. 5% Nital etch. X 3/4

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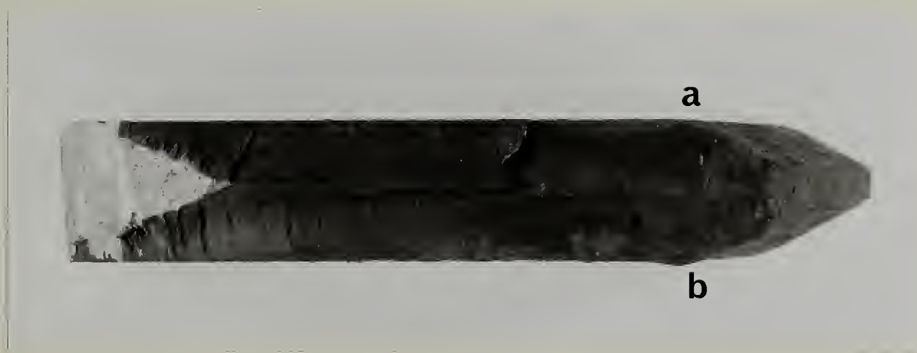
Figure 3. Upstream portion of Howell-Bunger Valve No. 1 showing crack in vane 4. Vane numbers are shown. X 1/2



670731

Figure 4. Fracture surface of vane 4. Upstream end is at right. X 3/4

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Figure 5. Fracture surface of vane 4. Upstream end is beyond right side of picture. X 3

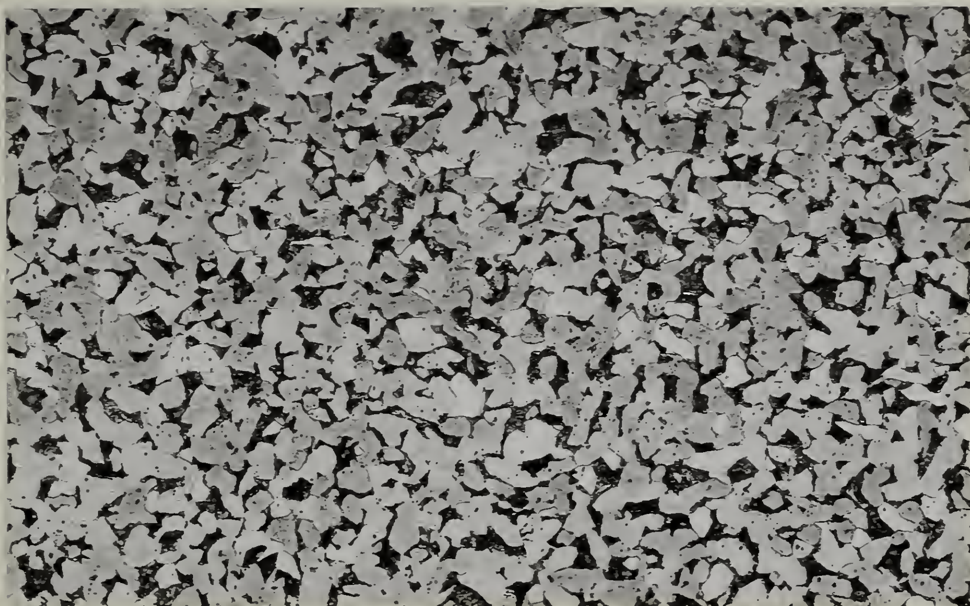

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Figure 6. Microstructure of hub. 1% Nital etch. X 100

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Figure 7. From left to right: hub microstructure, area of lack of welding, and heat affected zone of vane. Note decarburization near surface of hub. 1% Nital etch. X 100

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Figure 8. Microstructure of vane 4. 1% Nital etch.
X 100

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Figure 9. Microstructure of vane 6. 1% Nital etch.
X 100

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Figure 10. Microstructure of weld material. 1% Nital etch. X 100

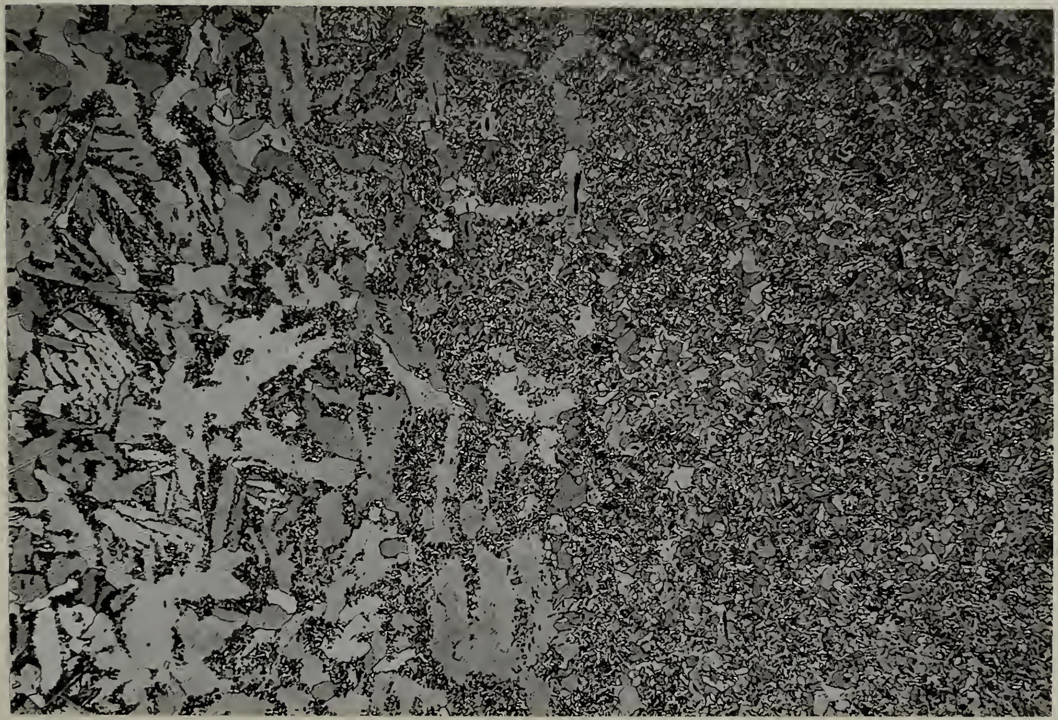

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Figure 11. Transition from microstructure of vane (left) to heat affected zone (right). 1% Nital etch. X 100

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