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TITLE: FIBER OPTIC QUALITY ASSURANCE AT THE NEVADA TEST SITE

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Fiber optic quality assurance at the Nevada Test Site*

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Abstract

A large number of fiber optic cables were used in support of a neutron imaging experiment at the Nevada Test Site. This paper describes the quality control testing of fiber components used on this experiment. The principle reason for quality control testing was to ensure reliable, high transmission fibers; a secondary reason was to gain data on a large sample of fiber cables in the field. Also described is the instrumentation developed for carrying out these field measurements. The design of the quality control instrumentation was a compromise between accuracy and simplicity of use.

Introduction

An overview of the experiment is described in a separate paper . A single fiber channel shown in Figure 1, from the array of 152 channels, consisted of both PCS (plastic clad silica) and GI (graded index) fibers. The PCS and GI fibers were connectorized on both ends. The PCS fiber had a ferrule of EG&G design on the end near the fluor cell and an ITT FON connector on the other end. A particular problem with PCS fiber is the need to strip the plastic cladding to firmly secure the fiber in epoxy for polishing. This removal of the cladding causes mode stripping in the connector and results in high losses. To combat the problem, a few-micron thick, low-index Optelecom coating was used to coat the core. The GI fiber had ITT FON connectors on both ends. A number of the GI fibers had fusion welds near the center of the cable.

Quality control measurements

Five parameters were evaluated; transmission at 800 nm, core diameter, numerical aperture, core concentricity, and skew angle. The measurements were done with an EG&G-built instrument (Figure 2). All of the measurements except transmission were made by taking a photograph on Polaroid film and making dimensional measurements on the film. The transmission measurements were made with a pig-tailed LED and a Photodyne radiometer. A typical

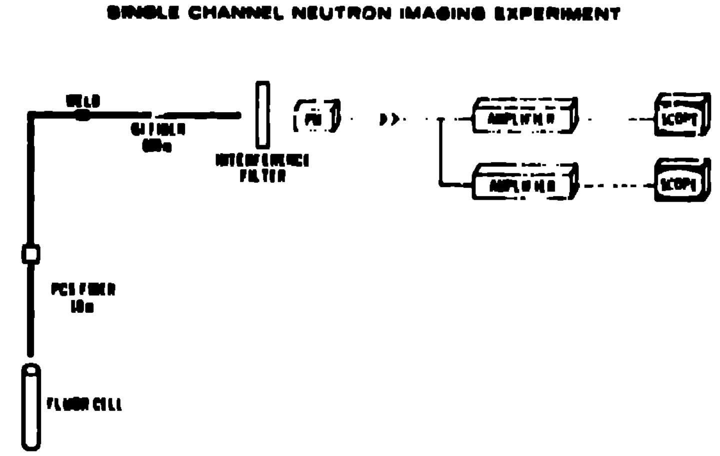

Figure 1. Block diagram of single channel in imaging experiment

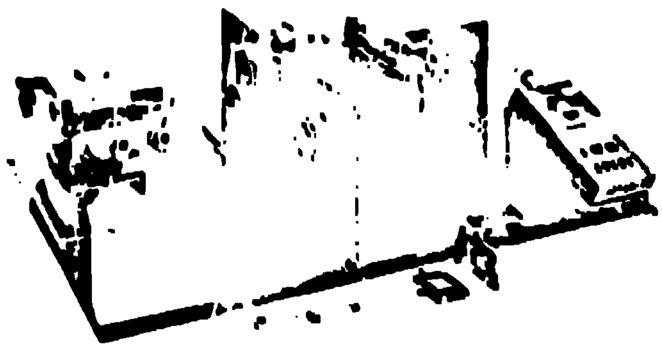

Figure 2. Hardware used in quality control measurements

quality control sheet (Figure 3) showing the data on one Siecor fiber also shows the photographs from which the data are extracted. Because the film is Polaroid and the data are extracted without using a microdensitometer, the accuracy of measurements is low compared to standard laboratory techniques. However, this system is able to process a large number of fibers in the field in a short period of time. A quick measurement of the photograph was done in the field using a template. Later, these measurements were rechecked in the laboratory.

For cables that were welded, the weld losses were measured with a Siecor optical time domain reflectometer (OTDR). The measurements were made from both ends of the cable. A typical OTDR data sheet showing Polaroid photographs of the Rayleigh back scatter is seen in Figure 4. Various sections of the oscilloscope traces are identified in Figure 5.

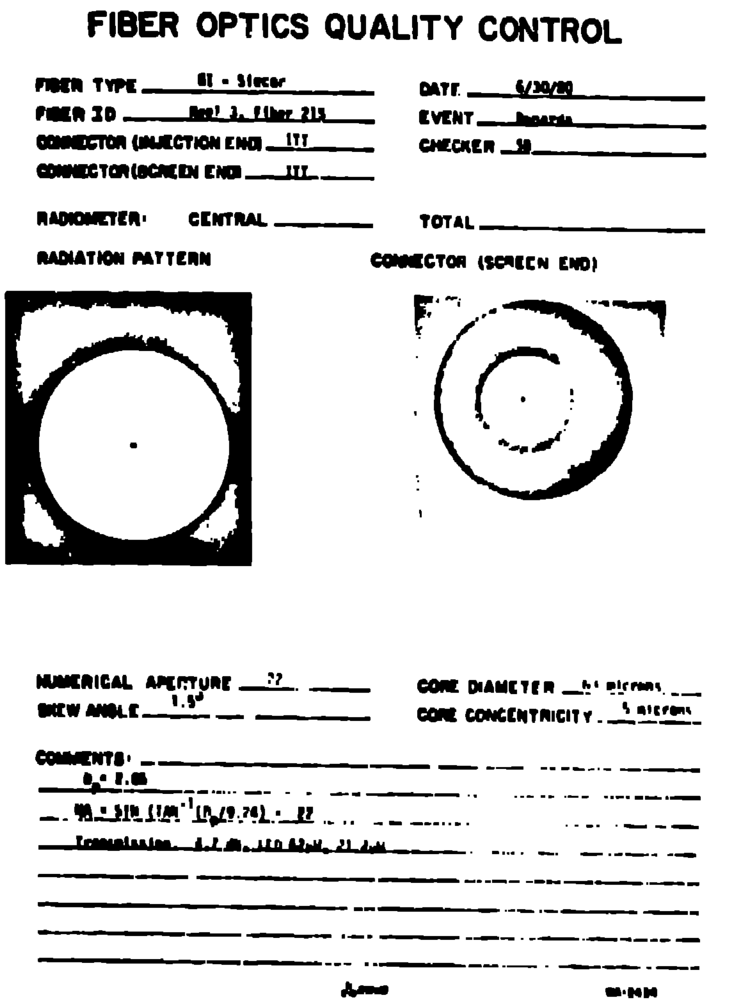

Figure 3. Typical quality control data sheet

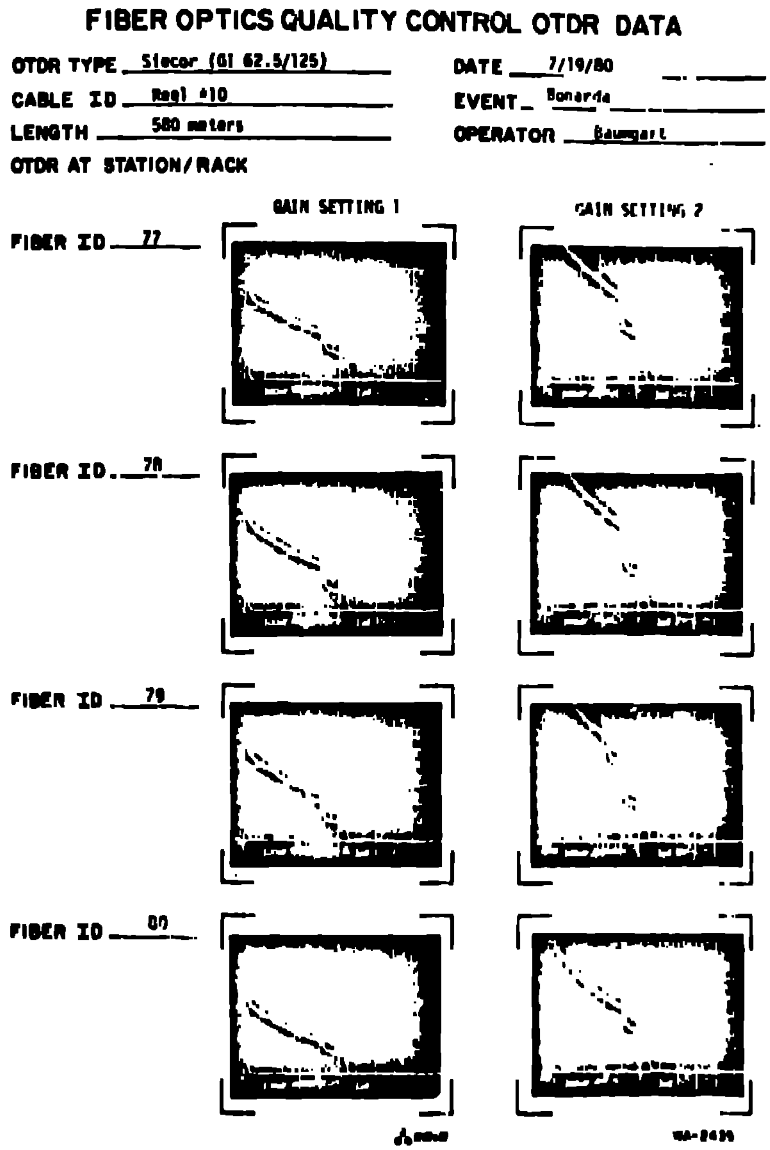

Figure 4. Typical OTDR data sheet

Figure 5. Oscilloscope trace obtained using an OTDR

Results

The measurements made, and their results, are summarized in Figure 6. Transmission measurements were made on both Siecor cables and PCS fibers. All other measurements were done for only the Siecor cables. Transmission measurements were made by two independent methods; pigtailed LED and OTDR. There was a systematic difference between the methods due to the inability of the OTDR to measure losses in the connectors. The average transmission value achieved was well below our rejection criteria. The transmission distribution for both the PCS fibers and Siecor cables are shown in Figures 7 and 8. Time constraints of the overall experiment forced the use of a few PCS fibers with higher losses than acceptable.

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TEST	METHOD		AVG.	MEASUREMENT UNCERTAINTY	REJECTION CRITERIA
TRANSMISSION	RADIOMETER + LED OTDR	[illegible] PCS + [illegible] [illegible] GI + [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
WELD LOSSES	OTDR RADIOMETER + LED		[illegible]	[illegible]	[illegible]
CORE DIAMETER	MICROPHOTOGRAPH		[illegible]	[illegible]	NONE REJECTED
NUMERICAL APERTURE	PHOTOGRAPHIC		.17	[illegible]	NONE REJECTED
CORE CONCENTRICITY	MICROPHOTOGRAPH		[illegible]	[illegible]	NONE REJECTED
WELD ANGLE	PHOTOGRAPHIC		[illegible]	[illegible]	[illegible]

Figure 6. Overview of fiber optic quality control testing

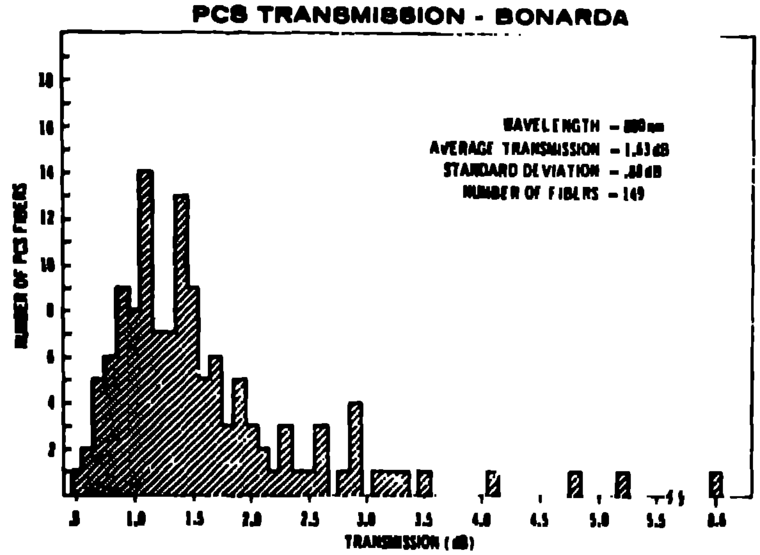

Figure 7. Histogram of PCS transmission

The weld losses (Figure 9) were measured with an OTDR. The dependence of the loss value on the direction of the measurement is not well understood. In part, the lack of symmetry may be in the weld itself. Variations in Rayleigh coefficients, numerical apertures, and core diameters between the two fibers welded may also contribute. The welding of Siecor cables was a successful venture. The welding and OTDR measurements required two man days per cable (8 fibers/cable) but the result (low insertion loss) made the effort worthwhile.

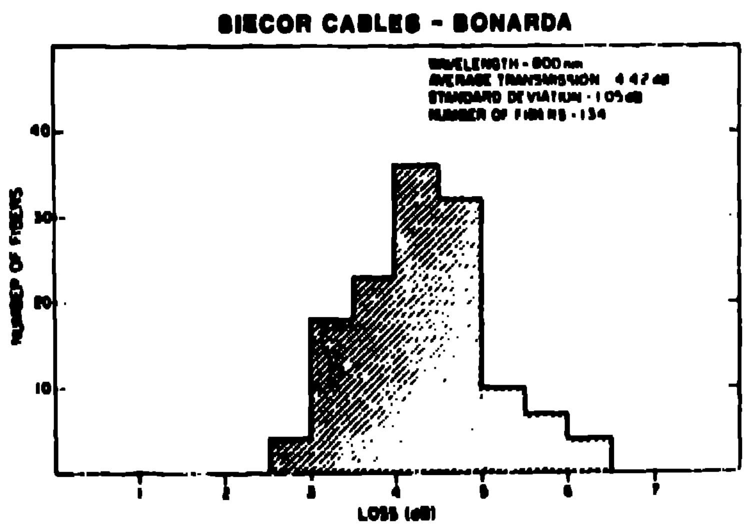

Figure 8. Histogram of GI transmission

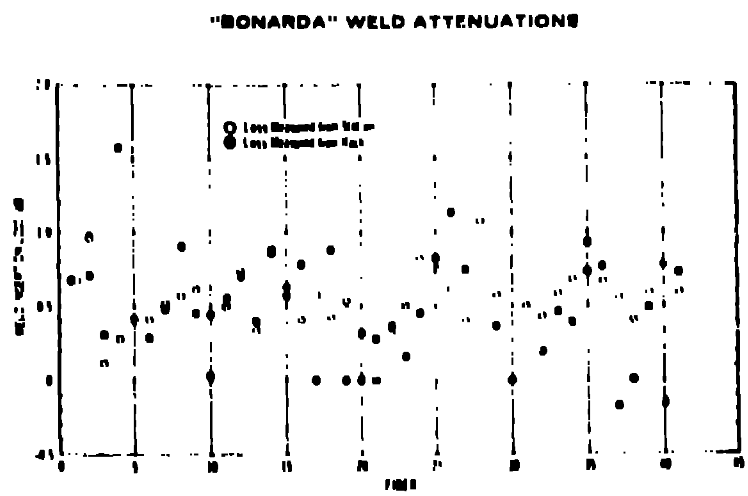

Figure 9. OTDR measurements of GI welds

Both the core diameter and core concentricity were computed using the same microphotograph. White light injected into one end of the fiber is photographed through a 400X microscope at the other end. The results (Figures 10 and 11) showed a surprisingly wide spread in these parameters. The core is over exposed in this technique. A comparison between the photographic technique and the more conventional measurement of the near field radiation pattern with a microphotometer revealed that the former technique corresponds to a core diameter at the 5% intensity level.

The numerical aperture and the skew angle were computed using the photograph of the far-field radiation pattern. The skew angle depends upon the connector used and the angular tolerances held in the polishing operation. With few exceptions, our results (Figure 12) were acceptable. The numerical aperture values measured (Figure 13) were also acceptable, however the spread of values was larger than expected.

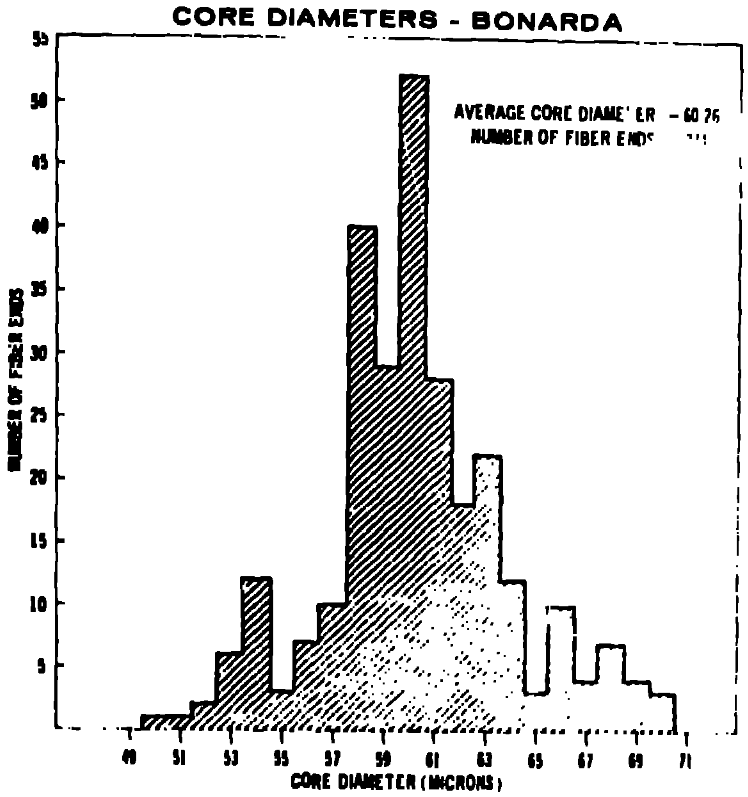

Figure 10. Histogram of core diameters

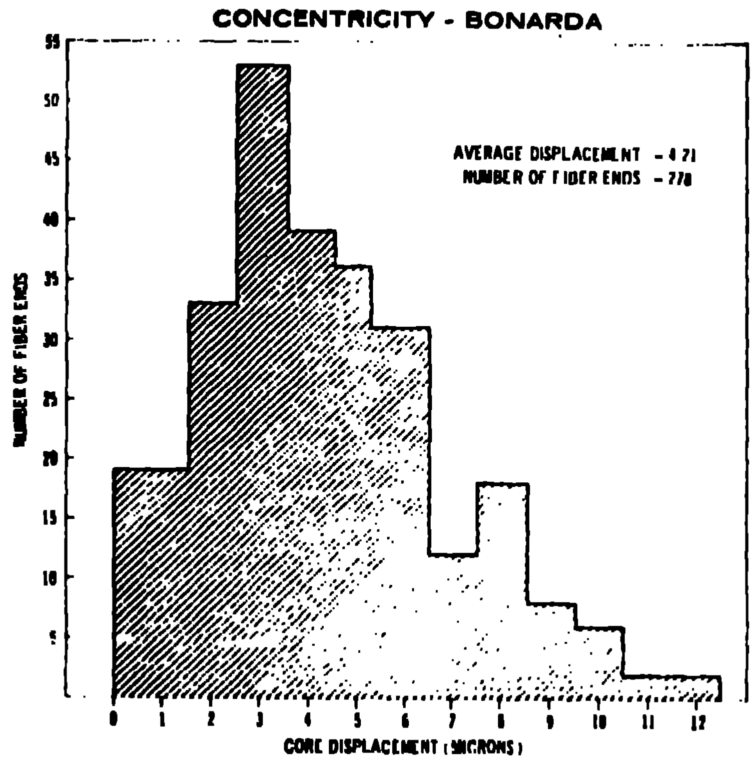

Figure 11. Histogram of core concentricity

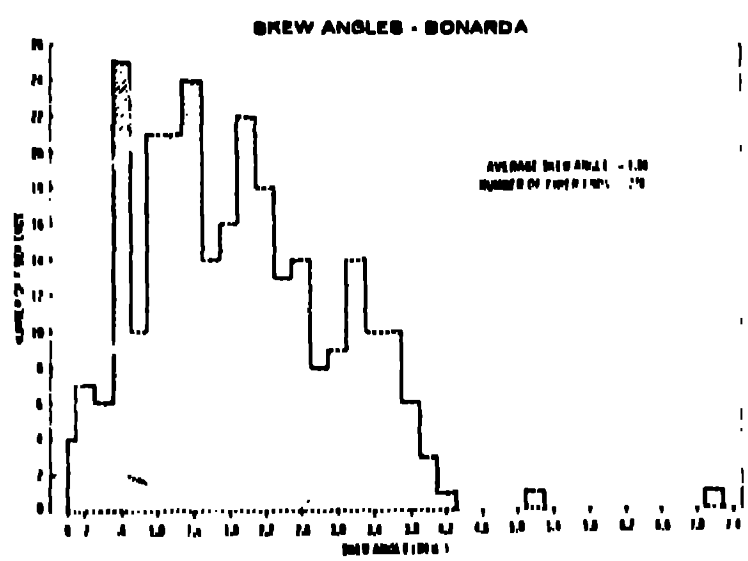

Figure 12. Histogram of skew angles

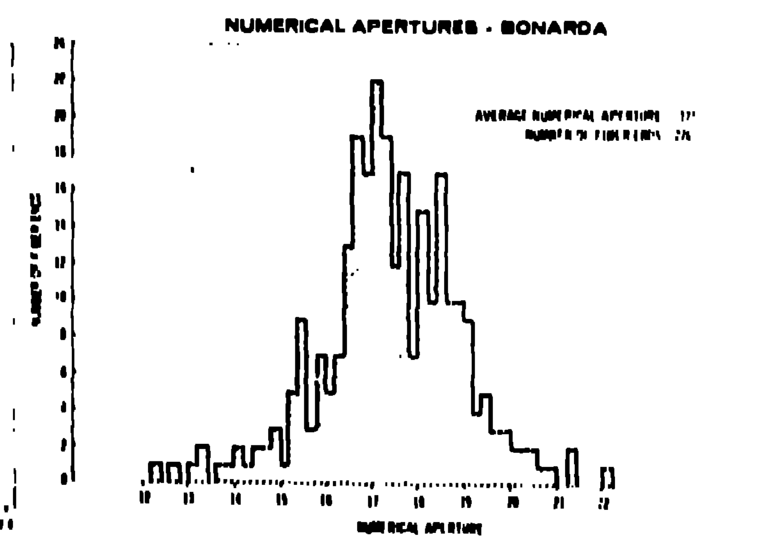

Figure 13. Histogram of numerical aperture

Conclusion

A hardware system for measuring fiber parameters in the field before final installation of the fibers was developed. This system was used on a large experiment requiring 18 fiber cables at the Nevada Test Site. The results showed a number of basic fiber parameters to have a larger spread than previously believed.

Acknowledgements

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