VSR Technology Group
The cost effective alternative to heat treatment

Report on Vibratory Stress Relief

Prepared by Bruce B. Klauba
Product Group Manager

VOITH SIEMENS
York, Pennsylvania

VOITH SIEMENS (was VOITH HYDRO) is a manufacturer of hydroturbine equipment used for power generation. When they received an order to replace 4 tons of cavitated cast steel in a 100,000 lb. Bottom Ring assembly, they chose the VSR Process to assure stability throughout fabrication and machining. The result was not only an 80 – 90% reduction of distortion at a critical stage in the fabrication process, but also a considerably more stable workpiece during final machining. These results convinced VOITH to use VSR TECHNOLOGY's vibratory metal stabilization system for future projects.

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...HELPING PRODUCERS EXCEL!®
7317 State Road, Philadelphia, PA 19136-4292

PH: 800.332.9770
FX: 888.964.3866

VOITH SIEMENS (now VOITH HYDRO) is a manufacturer of turbine components and systems for the hydro-electric power industry. They also offer repair, rebuild and upgrade services for this type of equipment. History on these types of repairs and upgrades (distortion problems and high costs of re-machining), forced management to explore best method technology to reduce the high costs associated with nn-stress relieved workpieces.

In 1993, VOITH SIEMENS received an order to refurbish a Bottom Ring, a very rigid, circular assembly which clamps around the bottom of a hydro-turbine housing, and houses half of the journals supporting the Wicket Gates used to control flow through the turbine. The Ring needed to be completely rebuilt because of severe corrosion and cavitation of the original steel castings. This type of repair work is becoming more frequent due to increased salinity in rivers throughout the world, especially at dam-sites near the Oceans. The repair required replacing more than 4 tons of cast steel with stainless plate in the 100,000 lb Bottom Ring. On a job this size, VOITH knew they had to find a solution to a problem they had experienced on similar jobs, *ie,* distortion of the two Half Rings (which make-up the Bottom Ring), after brace removal and subsequent machining. Most of the stainless steel would be used in the 1.5"Thick liner on the Bottom Ring's 225" ID. History on this type of repair showed that VOITH had regularly experienced Bottom Ring distortion of 0.25" to 0.50", with some Rings distorting more than 0.75". To compensate for the problem, VOITH engineers planned for up to 0.25" of stock removal to achieve final dimensions.

VSR TECHNOLOGY was asked to design a stress relieving procedure which would alleviate the dimensional stability problems that occurred at two critical stages in the refurbishment process.

1. Upon removal of the braces used to maintain Ring diameter during welding. Often, a Half Ring would close or tighten against a brace, making it difficult to remove. Sledging the braces out was often required. After brace removal, a Ring frequently distorted to the point where the distortion exceeded the allowed, or planned for stock removal in final machining. Additional corrective steps, such as straightening, would then be executed.

2. During machining of the assembled Ring. It was common for movement to take place after releasing the Ring from VOITH's large VTL. To address this problem, the Ring would be machined incrementally, and then released. Although this allowed the vast majority of the distortion to occur prior to final machining, it still required additional (sometimes 3 or 4) machining setups with the attendant increases in time and cost.

An effective stress relief process was needed to minimize the distortion of the Half Rings that occurred during brace removal, and also to significantly reduce the machining process to one that was more acceptable: rough machining to remove the majority of stock, machine release, and only one additional setup to perform final machining.

Having had experience with similar problems, VSR TECHNOLOGY's proposed using its VSR 790A System to perform three treatments on each Half Ring:

1. After the material to be replaced was machined away;
2. Midway through the welding process;
3. After welding was completed.

This 3 treatment procedure was necessary to assure that new stainless material was being added to dimensionally stable material (post Treatments 1 & 2), and that the workpiece would be ready for brace removal and machining after stress relief Treatment 3.

SET UP

A half Ring was placed on three (3) isolation cushions, with the cushions placed far from the ends. This configuration not only minimized damping of the workpiece, but also maximized its ability to resonate.

The Vibrator was securely clamped above one of the cushions, about 1/3 of the distance along the arc of the workpiece. Both the vertical and horizontal axis of rotation were tested, which necessitated using both sets of the Vibrator's dual mounting feet to determine which was more effective in resonating the workpiece. The horizontal Vibrator orientation proved to be superior.

The Vibrator's unbalance was adjusted to 15% of its maximum. Later, this was increased to 25%, which was the amount needed to cause a VSR Response, *ie*, a change in the resonance pattern which is displayed on the VSR 790A System's XY Plotter. This VSR Response embodied a resonance peak growth of approximately 30%, plus a slight lowering of the resonance frequency (15 – 40 RPM, centered ≈ 4,200 RPM), which is a classical Response on a workpiece of this configuration.

An Accelerometer (an electronic sensor with an output proportional to acceleration) which supplies the vibration data, was clamped on the corner of the workpiece that was farthest from the Vibrator. The Accelerometer's output was sent to the instrumentation-grade amplifier (linear to within ± 0.2% over a range of 1g to 50g), contained in the 790A's Control Console.

The System's tight regulation of the Vibrator's speed (≥ 0.05%), and its capability of allowing Vibrator speed adjustments in increments of one RPM, when combined with the precise acceleration data, enables even subtle changes in either resonance frequency or intensity to be detected, monitored, and recorded.

RESULTS

Prior to brace removal, punch marks were placed at strategic points along the ID of each Half Ring, and measurements between the punch marks were recorded so that subsequent distortion could be measured and documented. The bracing was then cut away. The braces, which previously required two men with sledgehammers to knock out, simply fell to the floor. Distortion measurements on each of the Half Rings showed movement of <1/16" (most, < 1/32"). *See* Brace Removal Distortion Map (Page 8). In fact, machined reference points on the assembled Bottom Ring were monitored during the machining cycle, and showed movement of < 0.009".

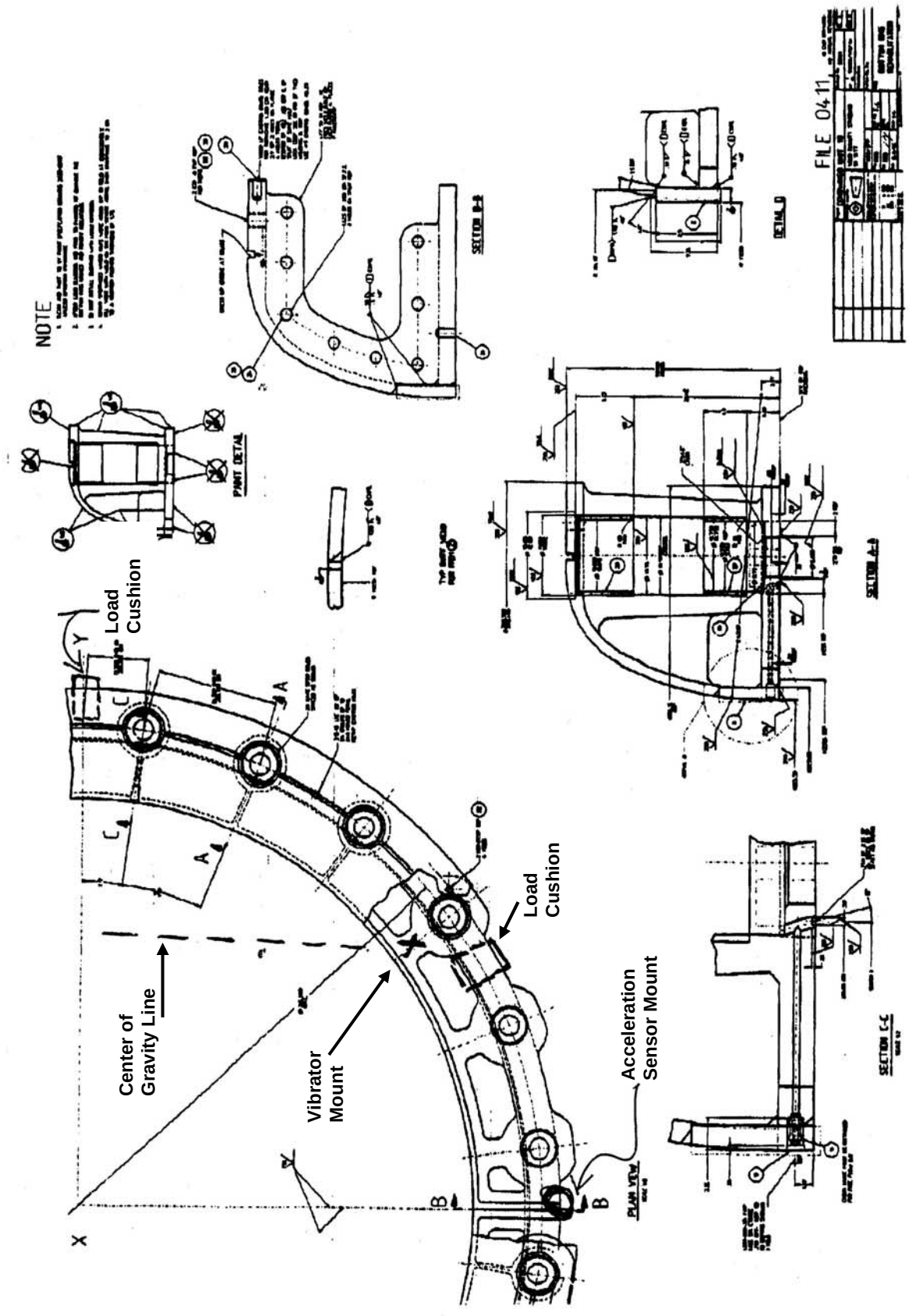
VOITH SIEMENS has learned that resonance pattern stability is equal to workpiece dimensional stability, and that the easiest way to stress relieve a wide variety of large, complex, and, often, bimetallic precision components is to utilize the VSR Process.

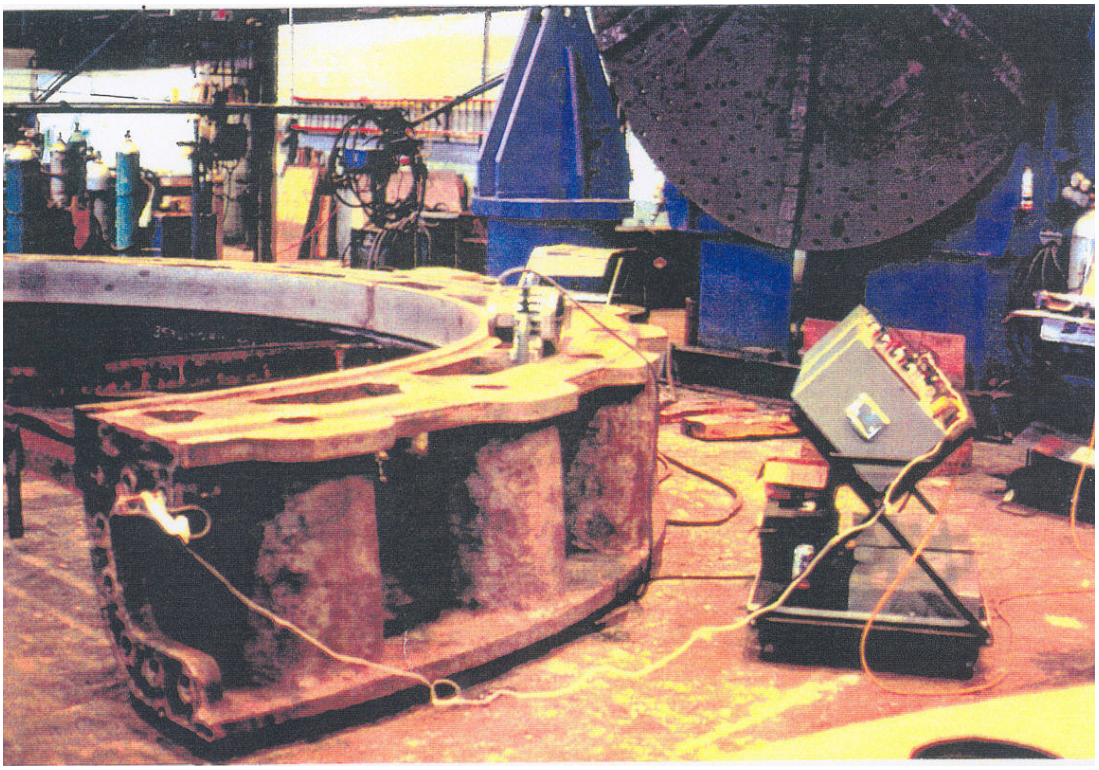
Bruce Klauba has a degree in Physics and a Level II Vibration Analysis Certification from the American Society of Non-Destructive Testing (ASNDT). As a pioneer in the cause and effect of Vibratory Stress Relief, Mr. Klauba was named chief inventor (*Klauba et al.*) in U.S. Patent 4,381,673, which is both an equipment and process patent describing advances in the technology. He has authored numerous articles and original research papers on the subject, which have been published in leading magazines and periodicals. Published papers include:

1. "Use and Understanding of Vibratory Stress Relief", *Productive Applications of Mechanical Vibration*, 1983, American Society of Mechanical Engineers.
2. "Vibratory Stress Relief: Methods used to Monitor and Document Effective Treatment, A Survey of Users, and Directions for Further Research", 2005, *Trends in Welding Research*, ASM International.

A co-author in both papers, Dr. C. Mel Adams, is a leading authority in metallurgy and co-founder of MIT's Welding Research Department. In addition, Mr. Klauba has extensive experience in designing, building, and troubleshooting Industrial and Commercial Electrical Controls with a focus on extending the performance and reliability of Electric Motors and the systems they power.

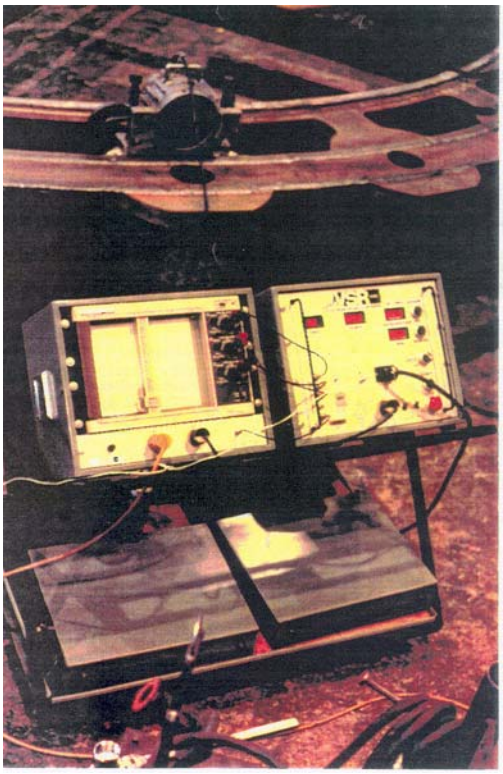
WORKPIECE DRAWINGS

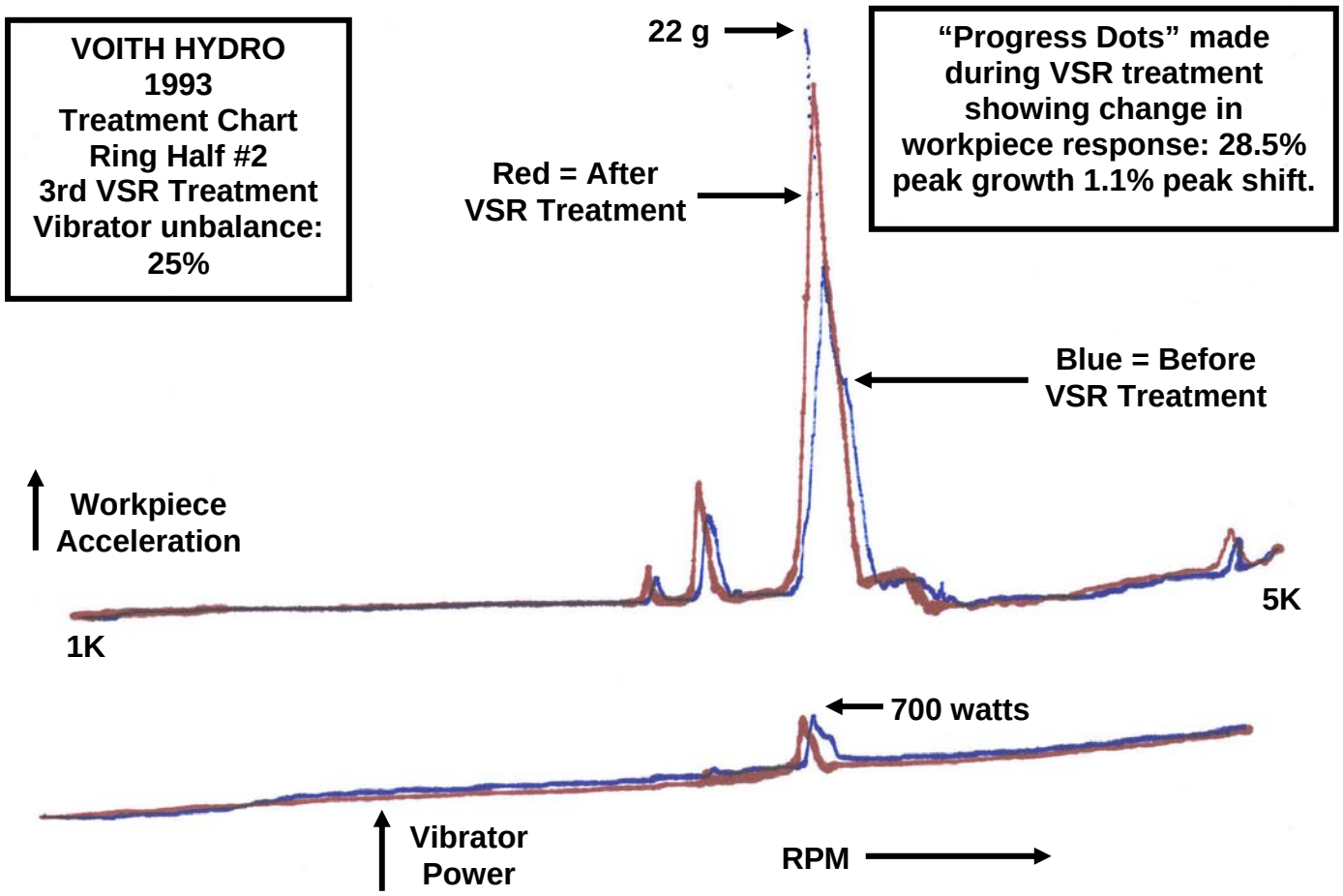




VSR setup. Three load cushions were used: one between the Vibrator and the Accelerometer; one midway along the arc of the workpiece, and the third at the far end, placed symmetrically opposite the one between the Vibrator and the Accelerometer.

Close-up of VSR 790A System:
Vibrator in background; Control Console on right; XYY Plotter on left. The CONSOLE houses the Vibrator servo-drive, accelerometer amp, auto-scan circuitry and controls – it enables the easy fine tuning of the Vibrator's speed in increments of one (1) RPM, with 0.03% speed regulation. The PLOTTER is used to generate Treatment Charts which enable effective set-up, monitoring in real time, and documentation of Treatment





A Treatment Chart automatically generated by VSR 790A System. The Chart's upper pair of curves show
workpiece response to vibration; the lower pair show Vibrator input power – both are plotted *vs* Vibrator RPM.

Pre-treatment data shown in blue; post-treatment in red. A Treatment consists of tuning to each of the blue peaks and then adjusting the vibrator speed – during growth or shifting of the resonance peak – until resonance pattern
stability is achieved.

During Treatment of largest resonance peak, the pens were momentarily lowered once each minute. This made a pattern of blue marks ("progress dots") which document the progress of the resonance changes as growth and
shifting take place. The lower dots are spaced far apart, which indicates rapid growth of the resonance peak; as these changes slow down (further up the peak), the dots are closer together, denoting less change. Further up the peak, the dots begin to cluster, meaning no additional

BRACE REMOVAL DISTORTION MAP

• = Punch Mark

Red before Brace Removal

Green after Brace Removal

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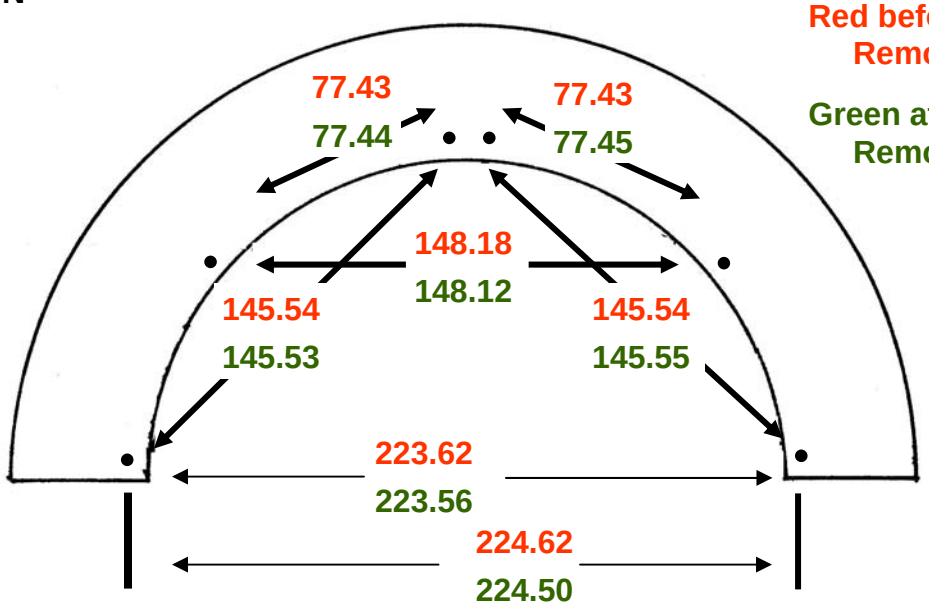

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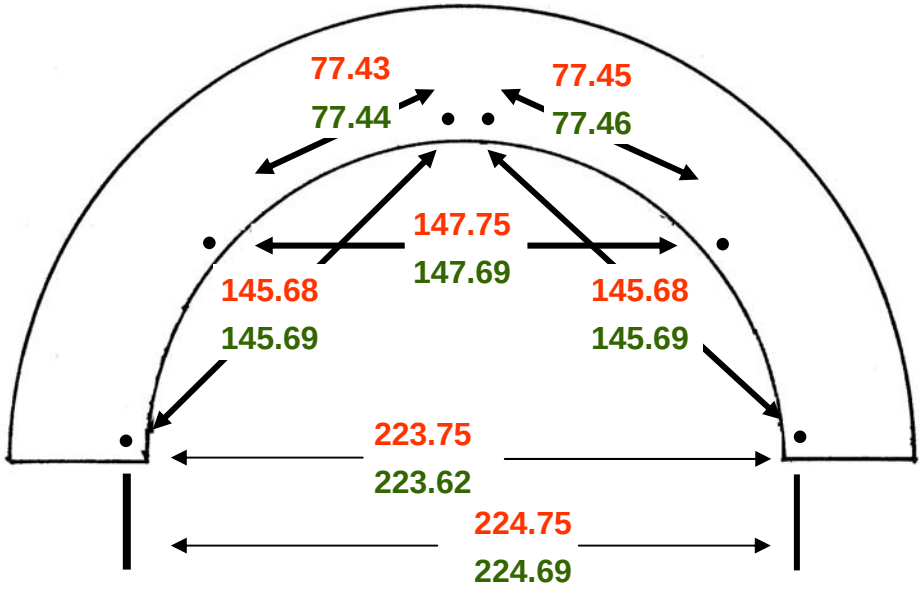

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