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GEORGIA INSTITUTE OF TECHNOLOGY
ENGINEERING EXPERIMENT STATION

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September 23, 1969

Mr. D. W. Van Doorn
Lummus Industries, Inc.
P. O. Box 1260
Columbus, Georgia

Subject: Failure Analysis of Ruptured Ram Plug

Dear Mr. Van Doorn:

We cut tensile test specimens from the ruptured ram plug mailed to us by Mr. J. B. Hawkins of your firm. It became apparent while machining one of these specimens that porous channels existed in one of the bars. Figure 1 shows the pore when first noticed.

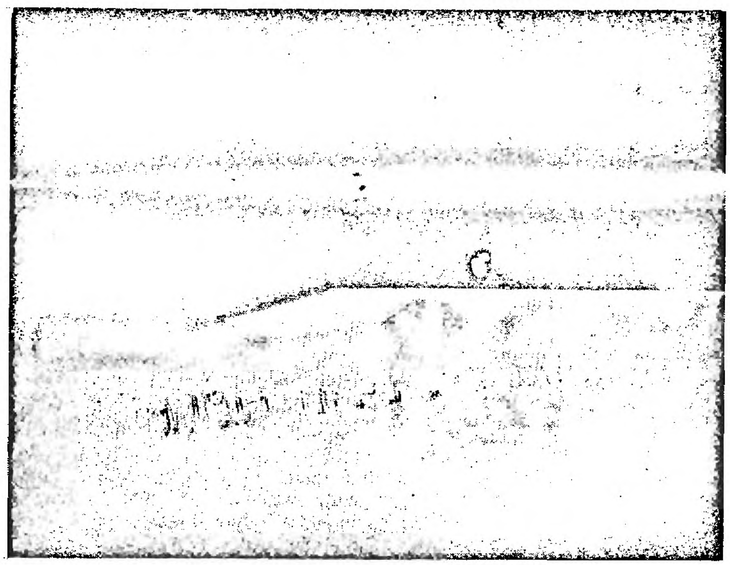

Figure 1. Porosity in Sample No. 2 test bar.

Figure 2 shows the pore after the bar had been turned down to the .500" test diameter.

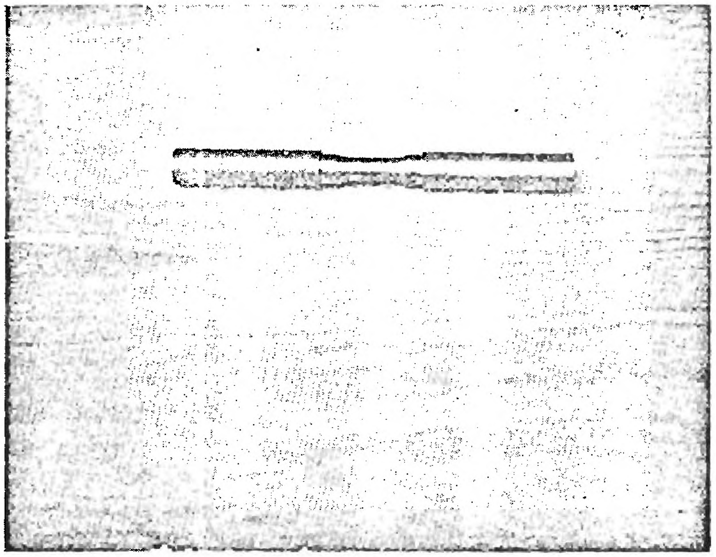

Figure 2. Sample No. 2 showing pore.

Figure 3 is a photomicrograph of the pore shown in Figure 2. Figure 3 is at

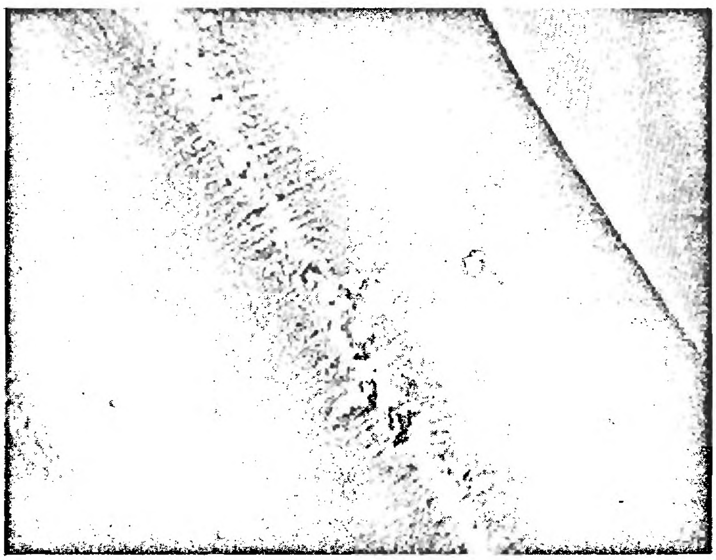

Figure 3. Magnification of Sample No. 2 pore 14x.

a magnification of fourteen (14) power. No significant porosity was noted in the other two bars. Figure 4 shows the location of the test bars with respect to their position in the ram plug.

Table I shows the failure loads and stresses of the three test samples. It is interesting to note that all three samples failed at remarkably close stress levels despite Sample No. 2 having an obvious hole. Sample No. 2 failed at the pore shown in Figures 1-3. It is also interesting to note that all samples failed at stress levels considerably below the 35,000 psi required by the specification.

Without going into an involved computer stress analysis of the plug, several approaches were taken to arrive at an estimate of the load-carrying capacity of the plugs. A stress of only 5270 psi was calculated for the point at which the section changes abruptly. This calculation was made using equations derived for uniformly loaded ductile plates with hubs. With a brittle material such as is used in the plug tested here, stress concentration factors of five to six are not uncommon. The factors arise from the inability of the brittle material to transfer loads from the thin section to the thick section and from the small fillet used at the change in sections. If these factors are multiplied times the calculated stress, we have an actual stress of 26,350 - 31,620 psi. These stresses are in the range of the true strength of the plug material and would indicate probable failure.

Due to the inability of the brittle plug material to transfer loads from the thin section to the thick section, a second approach was taken to determine the stresses. It was assumed that the thick section contributed little to the strength and could be ignored. The stress of the center of a uniformly loaded plate 1.875" thick was calculated. This was determined to be 26,641 psi. Again we have a stress level high enough to likely cause failure.

All of the calculations are based on a cylinder pressure of 4250 psi. Based on these calculations, the result of the physical tests, and the use of a safety factor of two; a maximum cylinder pressure of 2125 psi should be observed when using the cast plug material. If the actual strength of the new material is as high as 60,000 yield, a safe chamber pressure would be 4500 psi.

Two approaches could be taken to improve the structural integrity of the plug. First, the use of a flat plate of a structural steel with good ductility as a replacement for the cast plug would greatly improve the design. This change would require a slight modification to the seal design to insure sealing. Secondly, use of eight (8) to twelve (12) bolts rather than four (4) to hold the plate or plug to the ram would decrease the stresses by about 25 per cent. This last change will help with the existing plug design as well.

If we can be of any additional help in regard to this problem or with other problems, please call me.

Yours very truly,

James M. Akridge

James M. Akridge
Project Director

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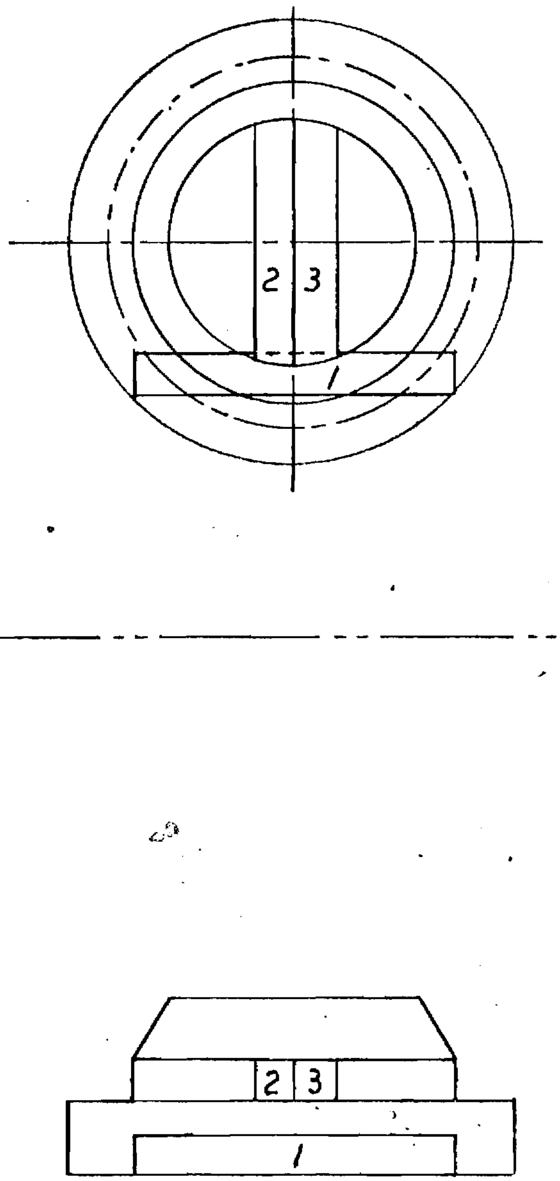

TEST BAR LOCATIONS

FIGURE 4

TABLE I

TENSILE TEST RESULTS OF CAST PLUG MATERIAL (1)

Specimen No.	Diameter (in.)	Aren ($in.^2$)	Load at (2) Failure (lbs.)	Tensile Strength psi
1	0.5021	.198	5150	26,010
2	0.5022	.198	5250	26,515 (3)
3	0.5016	.1976	5300	26,822

(1) Tested according to ASTM E 8-61.

(2) Tested at a load rate of approximately 4000 lb/min.

(3) This specimen had pore shown in Figures 1, 2, and 3.