608

XA0055848

# FORGED HOLLOWS (ALLOY 617)

## for PNP-Hot gas collectors

by F. Hofmann

VEREINIGTE DEUTSCHE METALLWERKE AG
Geschäftsbereich Nickel-Technologie
D-5980 Werdohl / West Germany

## Introduction and Purpose

When the partners of the PNP-project decided to manufacture PNP-components, such as hot gas collectors, from material of the type "alloy 617" (DIN material No. 2.4663) the problem was encountered that the required semi-fabricated products, especially forged hollows weighing several tons each, were not available. Also at that time it was not known, whether products in this high alloyed high-temperature material could even be produced in the required dimensions. As VDM had already gathered experience in the production of other semi-fabricated products of this alloy, attempts were made based on this knowledge to develop manufacturing methods for forged hollows. The aim was to produce hollows as long as possible, to keep costly welding to a minimum. Welded seams are always critical, during fabrication, as well as on later inspection under actual operating conditions. On the other hand, of course, the economics of the production method had to be kept in mind in reaching the goal of this development.

A three stage plan illustrates the development aims, whereby stage 3 is currently being worked at (figure I). The first two stages involved the production of forged hollows for hot gas collectors for 10 MW heatexchangers designed by Steinmüller/ Sulzer and Balcke-Dürr. Stage 3 encompasses the development of necessary forgings for a hot gas collector for a future 125 MW heatexchanger. As, according to current thinking, this entails approaching the limits of what is technically feasible and as such involves a high economical risk. This project is subsidized as part of the overall PNP-project.

## Procedure

A prerequisite for this project were the previously started investigations studying the influence of the melting method on the most important properties of the alloy, as for example the creep rupture properties at high temperatures. These investigations revealed, that the expensive method of melting and casting under vacuum (VIM), which is frequently stipulated for such material, is in fact not necessary. This alloy can be melted in an open electric arc-furnace, similar to highly alloyed stainless steels in large heats of for example 30 tons, and cast into ingots after a VOD treatment.

The advantage of this method is that it facilitates the use of economical raw materials through corresponding metallurgical treatments, as well as the production of large ingots. Large ingots, however, have to be remelted to minimize segregations in the ingot. These are caused by elements such as chromium and molybdenum which have a great tendency to segregate. For remelting, the electroslag remelt process (ESR) was chosen. Compared to other remelt methods, it is economical and offers certain advantages during subsequent fabrication.

Figure 2 shows the relationship of creep rupture properties of alloy NICROFER 5520 Co (Alloy 617) to the respectively discussed melting methods. This diagram clearly reveals that the melting method selected for this project does not adversely affect the creep rupture properties of NICROFER 5520 Co (Alloy 617) particularly at high temperatures. A heat which was melted and cast under vacuum was used as reference. Of the two casts investigated, it was found that the creep rupture properties were actually better above 850 °C for the VOD/ESR processed heat as compared to the material melted and cast under vacuum.

For stage 1 of the project, remelt ingots of approximately 750 mm in diameter with a weight between 6 to 7 t were produced according to the melting method described. After dressing, the ingots were heated up to the forging temperature, upset forged (figure 3), pierced with a mandrel (figure 4), and forged to final dimension over a mandrel in several forging steps (figure 5). Prior to the final forging operation, it is important to homogenize the forgings in order to reduce unavoidable microsegregations. The temperature during the last forging operation is of great siginificance as it determines the properties of the forged part lateron. Thus the forgings must be sufficiently and uniformly deformed to obtain a defined grain structure during the final thermal treatment (fig.6). This thermal treatment is carried out within the temperature range 1150° - 1200 °C. With this thermal treatment an average grain size of ASTM 0 could be attained. This avoids any problems during ultrasonic testing of the forged hollows for interior defects. The inspected forgings (figure 7) were then machined to final dimensions (figure 8). This production step also necessitated detailed investigations, as alloy NICROFER 5520 Co (Alloy 617) is very difficult to machine.

For stage 2 of the developmental work, i.e., for the production of a forged hollow, approx. 2000 mm in length, a larger ingot was needed to obtain the desired final dimensions. In this case an ingot 850 mm in diameter and weighing approx.8,5 t, was chosen. Fabrication parameters, similar to those used during stage 1, could be applied. The increased occurance of microsegregations caused by the larger ingot diameter had to be compensated by suitable homogenizing treatment. On this occasion, it was noted, that the operating limits of a 7000 t forging press was reached at individual deformation stages. During final inspection the hollows were shown to meet the specified properties and were consequently further processed to hot gas collectors by the fabricators. (figure 9)

Currently work is persued for stage 3 of the developmental project which entails production of a forged hollow for a hot gas collector for a future 125 MW heatexchanger. At least in the area of critical temperature the hot gas collector should consist of one piece, i.e., it should be approx. 4000 mm in length. After reviewing the forging capacities of suitable equipment available in West Germany, it was determined that an ingot, 1000 mm in diameter and 2700 mm in length, weighing approx. 17 t was required. For this highly alloyed material, which is very prone to segregations as already mentioned, this is certainly a most unusual size, which probably has never been produced in the past.

During processing the remelted ingot unsuspected problems were encountered during electroslag remelting. These, however, were overcome by adapting process parameters, involving for example the development of a suitable slag. Figure 10 shows the cast ingot with a diameter of 1000 mm x 2700 mm and a weight of 17 t. After dressing the surface, the ingot was heated up to forging temperature. The ingot had to be upset forged directly without a supporting fine grained shell. Upset forging was carried out with a forging power of 9000 t. In two stages the ingot could be reduced approx. 50 % in height by upset forging to 1300 mm. The ingot was forged back to its original shape and once more upset forged to 1300 mm. This rather costly procedure was deemed necessary to obtain an allround homogeneous deformation of the ingot structure, as well as a breaking up of the segregation zones for the subsequent homogenizing heat treatment. The ingot was then pierced with a 300 mm diameter mandrel. Before forging could be continued, the rough forging had to be dressed, to remove upset folds and cracks inside the hollow. During further processing of the forging, problems were encountered with widening and stretching, as the available tools, i.e., the forging mandrels were breaking due to insufficient strength. This problem was overcome by forging in the upper forging temperature range, which necessitated frequent reheating. The final dimensions attained were o.d. 1050 mm and i.d. 780 mm with a length of 4400 mm (figure 11).

In order to determine the thermal treatment procedure a sample ring approx. 300 mm in length was cut off. This sample ring was given a trial heat treatment in the annealing furnace foreseen to be used for the actual forged hollow. Results obtained so far, indicate a structure essentially free of segregations with an average grain size of ASTM 0. Utilizing these experimentally determined heat treatment parameters, final annealing of the actual forged hollow is currently beeing conducted.

## Future Outlook

Following completion of the thermal treatment of the forged hollow, it is planned to take samples in various places, in order to examine the properties of the alloy in the existing product form.

This should particularly show, whether production of forgings of that dimensions are technically and economically feasible in sophisticated nickel alloys such as NICROFER 5520 Co (Alloy 617) in future. This is of importance, not only for the PNP-project, as other applications also require at least the capability of producing large ingot sizes in similar alloys. Up to now this could not be considered to be the latest state of the art, due to the high production risks involved.

As an extension to this development, it is planned to utilize the forged hollows, to study economic joining methods, such as narrow gap submerged arc welding. This additional work focuses particularly the question of economics. Initial experiments have been conducted and can be said to be promising.

614

Abb. 1

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|---|---|---|
| VDM | Stufenplan zur Entwicklung geschmiedeter Hohlkörper aus dem Werkstoff Nicrofer 5520Co (alloy 617) | NQW |

| | Hohlkörperabmessung | Blockgewicht |
|---|---|---|
| Stufe 1: | ca. 1090/740 Ø x 1000 (mm)<br>Roh-Gew. ~ 5 to | ca. 6,7 to |
| Stufe 2: | ca. 880/550 Ø x 2100 (mm)<br>Roh-Gew. ~ 6,5 to | ca. 8 to |
| Stufe 3: | ca. 1050/780 Ø x 4400 (mm)<br>Roh-Gew. ~ 16,6 to | ca. 17 to |

Fig. 1 Plan of developmental work

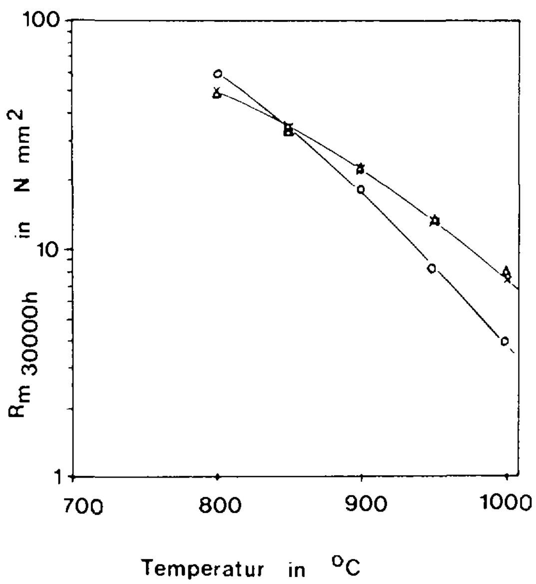


Fig. 2 Creep rupture strength of NICROFER 5520 Co (alloy 617) related on melting procedure ( O VIM; x▲VOD/ESR)

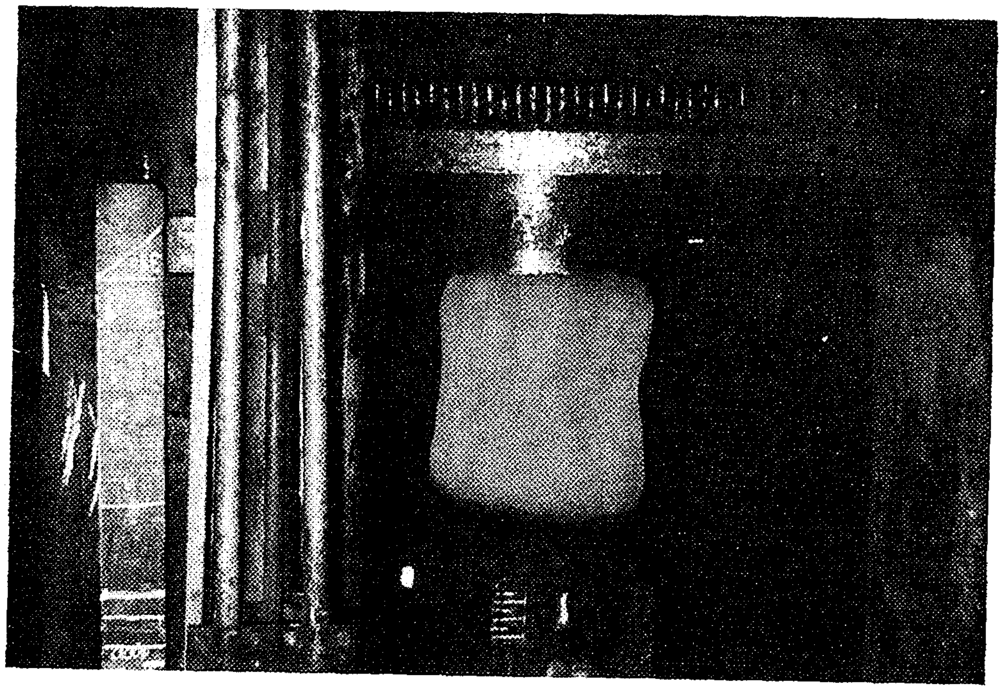

Fig . 3 Upsetting of the ingot

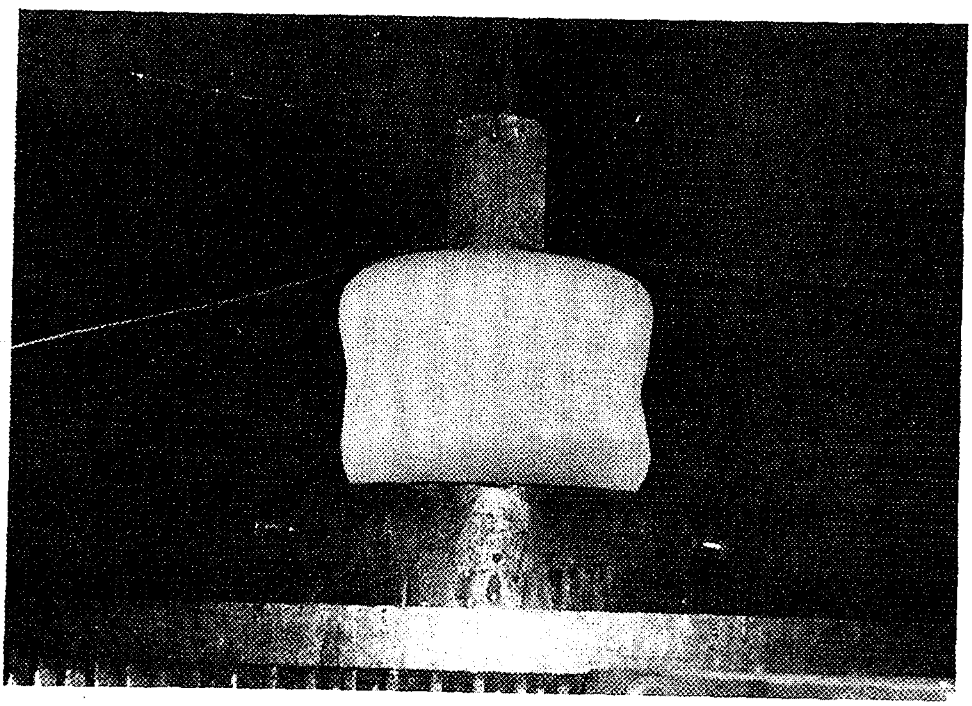

Fig. 4 Piercing of the upset ingot

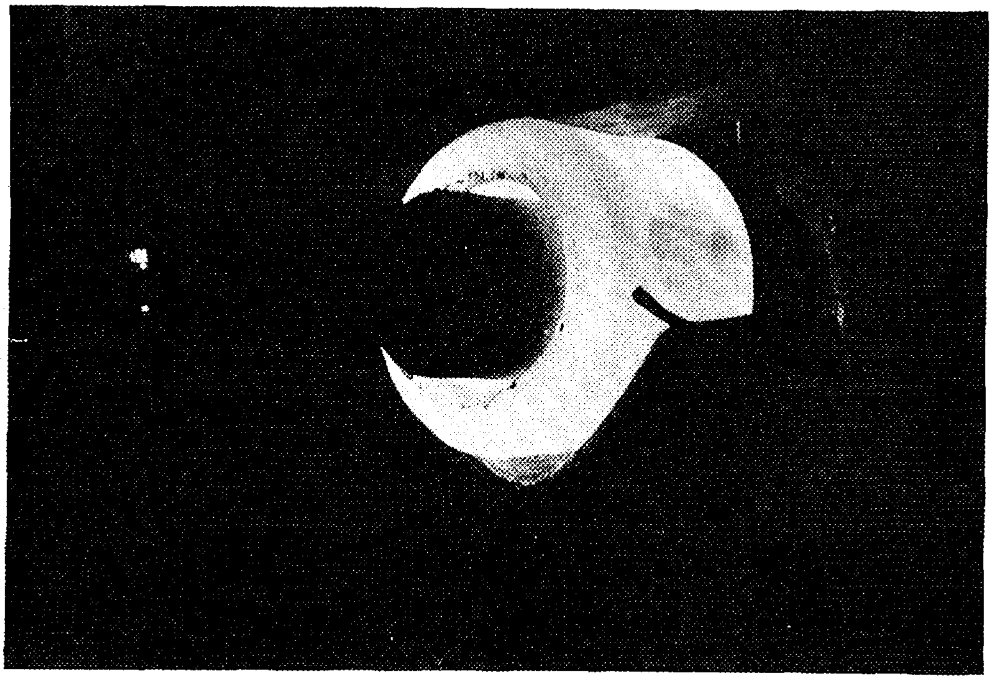

Fig. 5 Widening of the pierced ingot

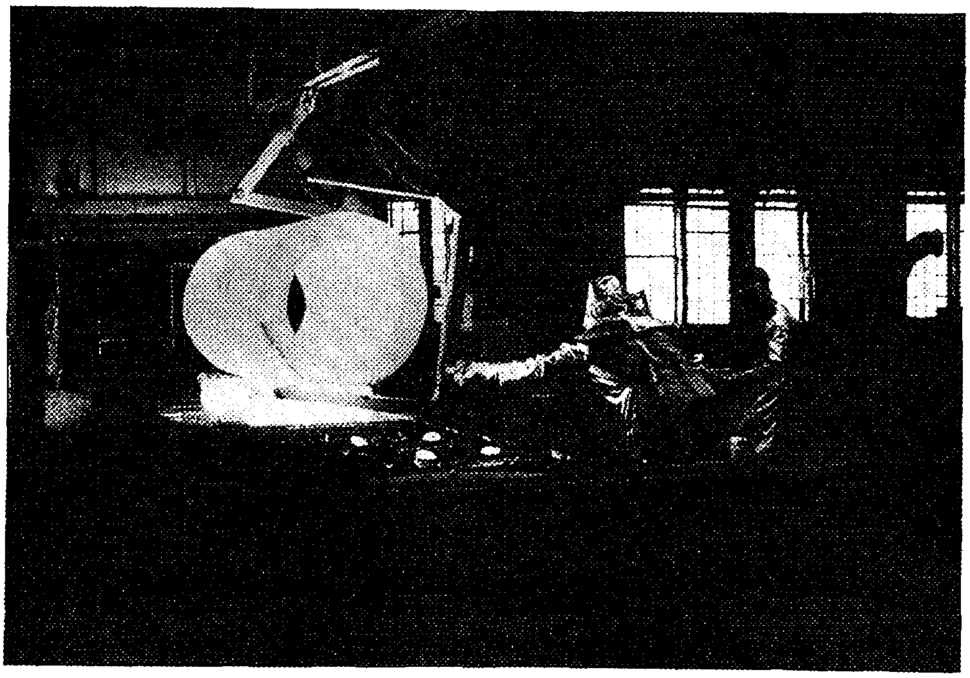

Fig. 6 Heat treatment of the forged hollow

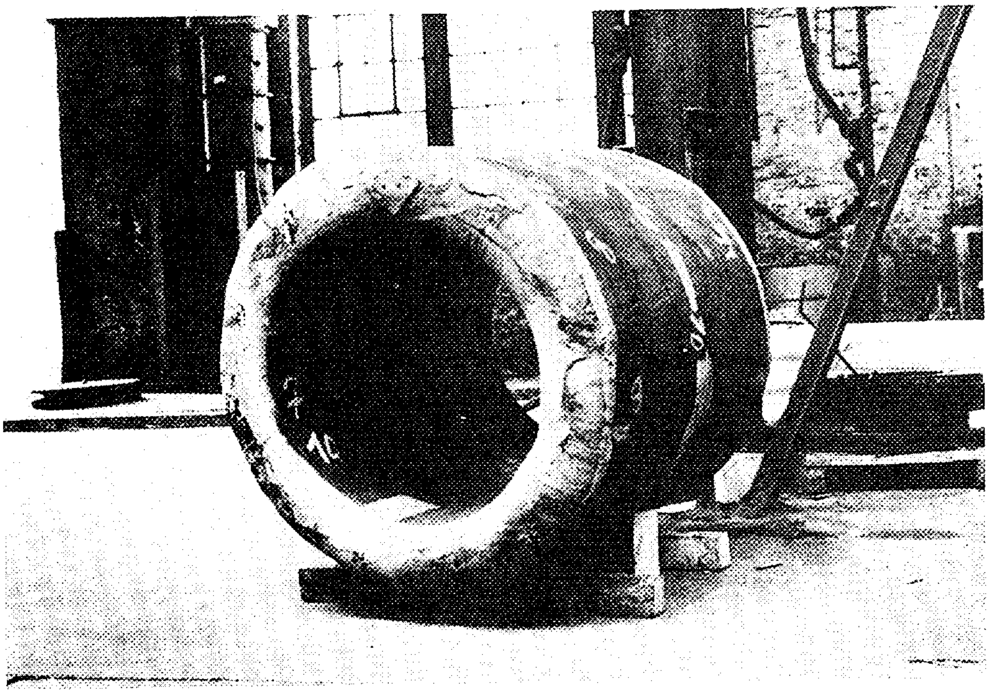

Fig. 7 Forged hollow before machining

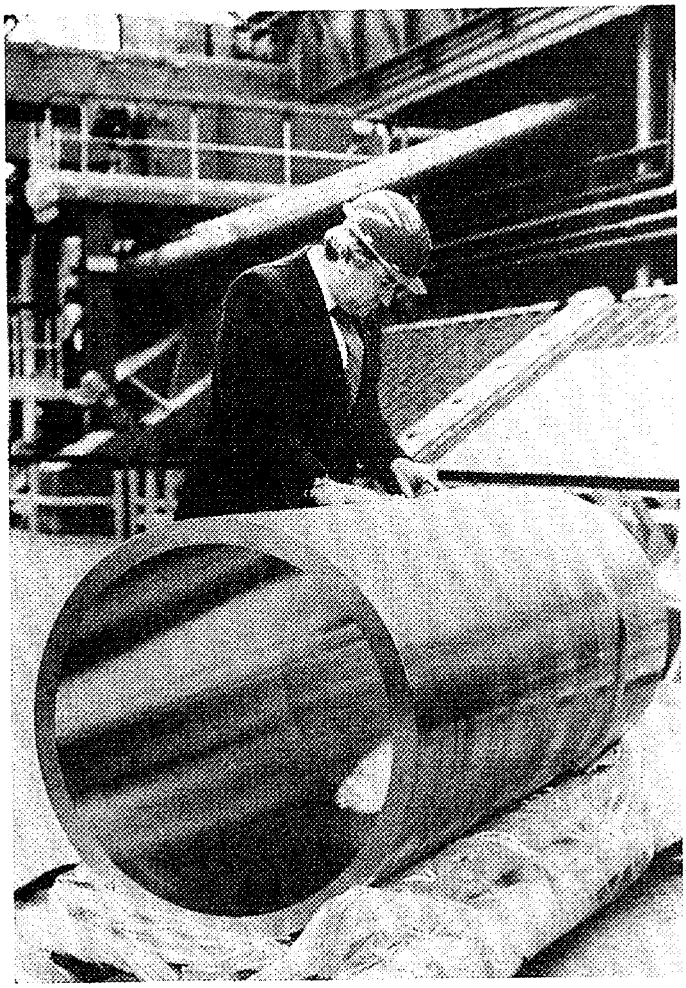

Fig. 8 Machined hollow ready for delivery

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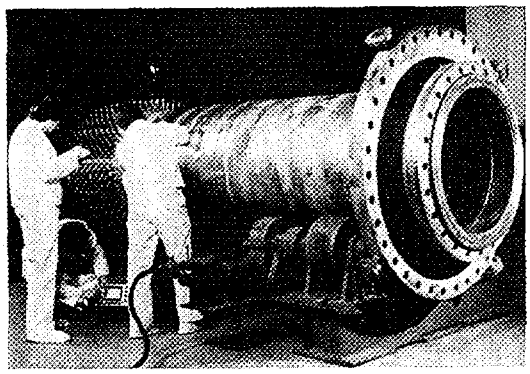
| VDM | Heißgassammler für U-Rohr Wärmetauscher aus Nicrofer 5520 Co (alloy 617) Konstruktion: Balcke-Dürr | NQW |



820/630 Ø x 1850
820/674 Ø x 1650
820/620 Ø x 265

Diese Abbildung setzt sich aus Teilstücke der Abmessungen: zusammen

Fig. 9 Hot gas collector for He/He heat exchanger
Fabricator: Balcke-Dürr

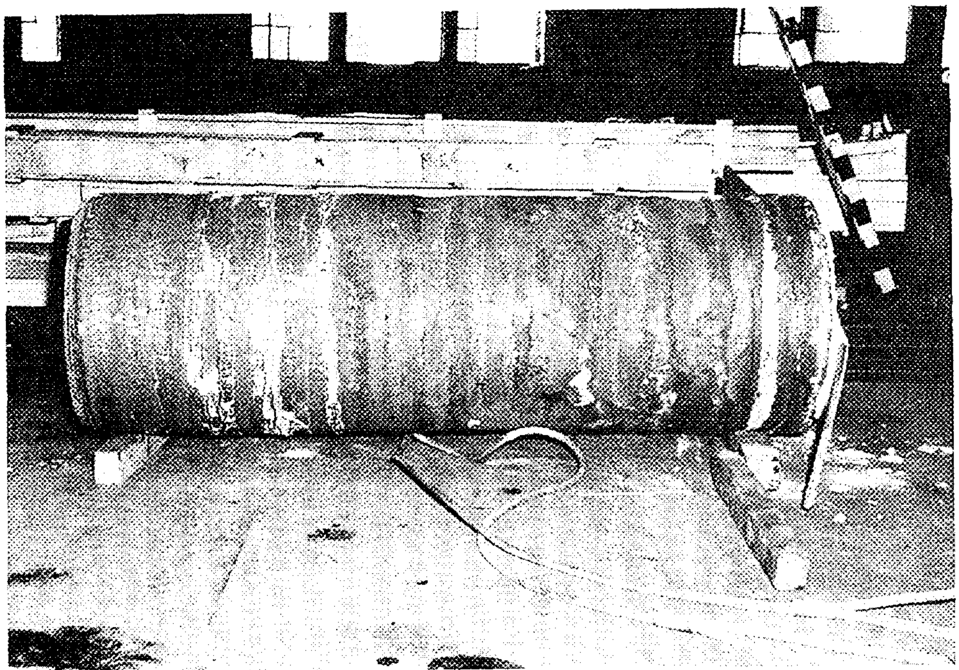


Fig. 10 17 t ESR ingot in NICROFER 5520 Co

VDM

geschmiedeter Hohlkörper aus Nicrofer 5520 Co
Schmiedeabmessung: 1050/780 Ø x 4400 mm

NQW

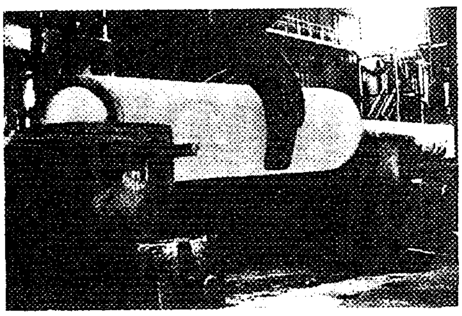


Fig. 11 Forged hollow in NICROFER 5520 Co
Dimension: o.d. 1050 mm i.d. 780 mm, length 4400 mm