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THE GERMAN SOFT IRON ROTATING BANDS
Report No. 8

R. #5991,
PC #4643.

June 4,1947

SAM TOUR & CO., Inc.
44 TRINITY PLACE
NEW YORK 6, N. Y.

R. #0551,
PC #4643,
June 4,1947

THE GERMAN SOFT IRON ROTATING BANDS

REPORT No. 8

Introduction:

Under the terms of contract W-30-069-ORD-4417, Sam Tour & Co., Inc. was commissioned to assemble all available information on the German sintered iron rotating bands. In the course of accumulating this information, a certain quantity of information concerning the German soft iron rotating bands, was also obtained. This report No. 8 is a record of this information pertaining to the soft iron rotating bands. Since this information was obtained, only incidental to the main objective of the work being carried out, it cannot be regarded as a complete study.

This report will be divided into the following sub-sections:

General Discussion
Methods of Manufacture and Assembly
Design Factors
Discussion of Firing Tests
Summary of Information
Recommendation for Future Work.

In presenting the information in the various sub-sections, efforts will be made to evaluate the adequacy of the information. Particular attention will be given to pointing out those instances in which the information presented may be either incomplete or unreliable.

Recommendations for future work will be predicated on the information contained in this report. It is recognized that additional information may be available to the Ordnance Department and that such information may modify the recommendations that are contained herein.

In accordance with the outline of reports given in Report No. 2 of the series being completed under Contract #W-30-069-ORD-4417, Report No. 8 was to have been written after the first seven reports were completed. At the request of the Ordnance Department, Report No. 8 is being written in advance of the writing of Reports No. 5, 6 and 7.

A reference list of the documents that had been consulted in compiling this report is attached hereto. These documents, together with English translations thereof, will be returned to the Ordnance Department upon completion of the work being carried out under Contract W-30-069-ORD-4417.

General Discussion:

The German soft iron rotating band was a tube or strip of specially annealed low carbon steel of the Armco Iron type, which was treated to produce very low yield and tensile strengths. The tensile strengths of these bands were in a range of 24 to 28 kg. per square mm. (33,500 - 39,000 psi) and yield strengths at 0.2% offset were in the range of 7 to 12 kg. per square mm. (10,000 - 16,000 psi). These low strength values were obtained by a controlled cold reducing or stretching operation followed by annealing at a closely controlled temperature. This treatment produced a very large grain size and thereby the low tensile strengths.

The soft iron bands, as finally developed by the Germans, required a particular band contour and a band seat somewhat similar to that used with sintered iron bands. References have also been made to the necessity of providing a lubricating channel in the band. This was to be filled with a special grease. No specific information was obtained regarding these questions of design and lubrication.

Rotating bands of low carbon iron were produced by the Skoda Works in the closing stages of World War I. Their development was initiated because of shortages of copper at that time. The development work was not carried to completion. However, it is believed that a certain number of successful soft iron bands were produced during the World War I. These bands were produced from tubing and were assembled by pressing on to the projectiles in the manner used for the assembly of copper rotating bands.

No comprehensive firing tests seemed to have been carried out and few records of the work were available to the German Ordnance Department at the beginning of World War II.

German interests in the soft iron rotating bands was revived in the early '30s. It is understood that some development tests were carried out at that time. However, the successful or apparently successful development of the sintered iron rotating bands discouraged interest in soft iron bands until after World War II had started.

In 1939, the Kaiser Wilhelm Institute proposed the use of a soft iron band which was to be specially treated to produce very low tensile strength. Their proposal was based on the previous development at the Skoda Works during World War I, but was modified by the inclusion of the special treatments that were intended to produce the very low tensile strength. The use of strip rather than tubing was advocated because it was believed that the cold work caused by setting of the band would be minimized with strip.

Their original proposal suggested that the strip be butt welded to form a joint. Early firing tests indicated that the welded rotating bands were unsatisfactory. No information is available as to why the welded bands were unsatisfactory. This led to the use of an undercut rotating band seat, somewhat similar to that used for sintered iron projectiles, into which the band was pressed. The two ends of the band were simply forced together with no attempt made to form a welded joint.

A study of all of the documents pertaining to both sintered iron and soft iron rotating bands indicates that, in general, the soft iron band development was undertaken to provide a band which could be used on projectiles over 8" in diameter and on projectiles for high velocity guns. It was also believed that perhaps the soft iron bands would be more suitable than sintered iron bands for the smaller guns from the point of view of erosion characteristics. It is definitely known that a soft iron band was required for projectiles over 8" in diameter because the Germans lacked press facilities of sufficient capacity to produce sintered iron bands of that size. For these large caliber projectiles, it was, of course, impossible to compare the efficiencies of sintered iron and soft iron rotating bands since sintered iron rotating bands in these sizes, were unobtainable.

Both soft iron and sintered iron rotating bands were used for high velocity projectiles. A series of general statements, contained in the documents studied in connection with this series of reports, indicate that the soft iron rotating bands were superior to the sintered iron bands for some high velocity projectiles. However, no firing test results to substantiate these general statements could be located.

It is believed that the German high velocity guns were primarily experimental models. Their standard guns were of the normal velocity similar to those used by the United States. It is doubtful that the Germans have any true evaluation of the relative efficiencies of sintered iron and soft iron rotating bands in high velocity projectiles.

For high velocity guns, the Germans found that rotating bands of the pre-engraved type were best. These were made of soft iron. The grooves into which the lands were to fit, were cut to 90% of the depth of the lands. The remaining 10% of the engraving was done during firing.

For 12" and larger projectiles, the Germans were experimenting with inlaid splines of low carbon iron. The inlays were about 1 to 2 calibers long. In high explosive projectiles, the inlays were spot-welded into slots in the projectile. For armor piercing projectiles, the inlays were upset into undercut slots similar to the type used in the standard rotating bands. No information is available as to how the upsetting operation was carried out. No information as to possible use of integral splines by the Germans was obtained.

A few firing tests were carried out with soft iron rotating bands in guns of approximately 105 mm caliber. These results, when compared to similar results obtained with sintered iron bands, indicated that, in the normal velocity gun, the sintered iron band was somewhat superior.

Development of the soft iron band was given added emphasis by plans to use them in Czech and Italian ammunition. Although these plans were made before it was found that the soft iron bands required an undercut rotating band groove, it was decided to produce Italian and Czech ammunition with the particular band seat design required for use with the soft iron bands. In addition, lack of capacity for the production of iron powder and of sintered rotating bands, prevented the Germans from producing a sufficient quantity of bands to permit the banding of both their own production and the production of the Italian and Czech.

Method of Manufacture:

German metallurgists, who were interviewed after the war, stated that the iron used for rotating bands should be of the Armco type. The "Armco" iron made in the U.S. has the following typical chemical analysis:

C -	0.012%
Mn -	0.017%
P -	0.005%
S -	0.025%
Si -	Trace

Much of the iron used in the manufacture of soft iron rotating bands had a chemical analysis as follows:

C -	0.08 %
Mn -	0.19 %
P -	0.014%
S -	0.032%
Si -	0.0[illegible] %

The German material differed considerably from the chemical analysis specified for American "Armco" iron. This difference was due to the fact that the Germans had difficulties in melting a steel of the analysis desired.

No information is available as to the method of deoxidation used by the Germans in the making of this steel. The question of deoxidation practice is extremely important in the making of steel for soft rotating bands. Certain types of deoxidation practices will result in a steel that will work-harden more rapidly than is desirable in rotating bands.

Ingots of this low carbon steel were rolled, by standard rolling procedure, to strip of a thickness of approximately 10% greater than that desired in the final band. It was then cut into appropriate lengths, and given a standard annealing treatment. After this annealing treatment, the steel was in a condition suitable for the special treatment required to produce the low tensile properties desired.

The special treatment consisted of a cold stretching of 10% or cold rolling of 10%. This produced a strip of the desired final thickness and in a condition of "critical cold work". After the cold work, the strip was annealed at 1250° F. for about 1 hour. This combination of "critical cold work" and annealing produced the large grain size in the strip and caused a "critical grain growth" which reduced the tensile properties to a minimum.

The exact times and temperatures of annealing that were required to produce minimum tensile properties were different for different lots of steel. Proper annealing cycles for each lot of steel were determined by laboratory tests.

Some of the German metallurgists, who were interviewed after the war, stated that, if the large grain size were produced by simply heating to temperatures in the range of 2000°F, the bands would be as satisfactory as those in which the large grain size was produced by the combination of "critical cold work" and "critical grain growth". Such a treatment would, of course, require the use of high temperature furnaces with hydrogen atmospheres to prevent oxidation of the surface during the heat treatment at high temperature. There are no records to indicate that the high temperature treatment was ever used in the production of soft iron rotating bands. However, this type of treatment offers a much easier way to produce large quantities of bands.

After, the bands were pressed into the groove of the projectile with band setters of the "tire-setter" type. The pressures used in setting were maintained as low as practicable and were just sufficient to force the two ends of the band together. No efforts were made to weld or otherwise join the two ends of the band when undercut band seat grooves were used.

A few investigations of the possibilities of re-annealing the band after setting were carried out by the Germans. Attempts to anneal by passing a heavy electrical current through the band were made. Other attempts were made to anneal the band by placing the end of the projectile in a conventional furnace so arranged that the forward end of the projectile could be kept relatively cool. Neither of these experiments were successful. The data upon which this report is being based, is insufficient to determine whether or not there was any real necessity of attempting to re-anneal after banding.

The German documents contained a brief mention of the advisability of treating the soft iron bands with a zinc plate, followed by a chromate dip which would produce a zinc chromate surface on the bands. It is believed that the chromate treatment mentioned is similar to the several commercial chromate treatments which are available in the U.S.

No record of the fact that the Germans investigated the adequacy of the zinc chromate treated rotating bands has been found. Tests of chromated zinc coating on sintered iron rotating bands, the results of which are discussed in Report No. 6, indicated that the zinc chromate treatment of sintered bands is most effective in improving performance. It is probable that the chromate treatment would also improve the performance of soft iron bands.

Physical Properties of Soft Iron Bands:

The mechanical properties of the cold rolled and annealed soft iron band strips were as follows:

Tensile Strength per sq. mm	Yield Point (0.2% offset) per sq. mm	Elongation	Brinell Hardness
20 to 28 kg	7 to 12 kg	No data	66 to 69

Tensile tests were made on the band stock only as a quality control measure. They were not an acceptance test. It was planned that acceptance testing would be based only on Brinell hardnesses of the band after setting on the projectile.

Design Factors:

The documents that have been studied in connection with this report, contained several references to the design of the rotating bands and the design of the profile of the band. References are also made to the necessity for a single "lubricating" channel in the band, and to the fact that the band seat of the projectile required for use with soft bands, is somewhat different than that required with the sintered iron band. It is believed that these details, which would be most valuable in the event of further investigation by the U. S. Ordnance Dept., can best be obtained from detailed drawings of Czech and Italian projectiles. Plans were being made to adapt at least the following types of projectiles for the use of the soft iron rotating bands:

Italian	7.5	cm	Anti-aircraft	
Czech	8.3	cm	A.Z. projectile	m30
Czech	15	cm	A.Z. projectile	m37

The details of these design features, which were not available for the compilation of this report, are essential in a complete record of the German work on soft iron rotating bands.

Firing Tests:

Practically all of the firing tests made by the Germans during the development of the soft iron rotating bands were made in a 105 mm. Howitzer. The bands used were of the strip type, made in accordance with recommendations of the Kaiser Wilhelm Institute and were not zinc plated.

The first few bands fired were so cut that the open joint in the band ran at an angle of 45° to the axis of the projectile.

These first firings indicated the necessity of changing the joint so that it ran parallel to the axis of the projectile. No information is available as to why this change was necessary. This, of course, changed the conformation of the band blank, so that it was slightly easier to produce.

Early firing also indicated the necessity of changing the profile of the band, and on standardizing on a single lubricating channel, filled with Skoda "Turga" lubricant. The initial production of the soft iron bands had several lubricating grooves. After preliminary firing tests had resulted in the standardization of band design, an accuracy-life test was carried out in June of 1941. A new 105 mm Howitzer barrel was used in this test.

An official German Ordnance Department document which discussed the result of these firing tests, has been included as Appendix A of this report. This document contained several references to photographs of the condition of the barrel during various stages of the test. These photographs were not obtained from the Germans and, hence, could not be included in the appended material.

This report indicates that the guns under test performed satisfactorily during a total of 6,899 rounds. During the firing tests both accuracy and maintenance of muzzle velocity were reported as being satisfactory. It was noted that, during the firing tests, the soft iron bands caused a deposit of iron in the barrel. This deposit was not wholly localized at the chamber end. It was distributed more uniformly along the entire length of the barrel

It was stated that some method of removing this iron deposit must be developed.

It was concluded, on the basis of this firing test, that the soft iron rotating bands were as satisfactory as the copper-steel bi-metallic bands that were currently being used for the large caliber projectiles. It was further concluded that some changes in the profile of the rotating bands and in the band seat groove of the projectile might improve the performance of the soft iron bands. This report also suggests that further improvement might be obtained through the use of zinc-coated soft iron bands.

It is believed that the test which has just been discussed is one of the few comprehensive firing tests that were carried out with soft iron rotating bands. The stress of wartime conditions, and the lack of materials, prevented the Germans from carrying out any but the most necessary types of test. It is believed that the use of the soft iron bands by the Germans was predicated almost entirely on the results of this single firing test.

<u>Summary of Information:</u>

It has been definitely established that the Germans used simple, soft iron rotating bands in the late stages of World War I. This development was revived in the early "30s, and dropped just prior to World War II when the sintered iron rotating band was developed. Shortages of copper and lack of press facilities to fabricate bands over 8" in diameter from sintered iron revived interest in the soft iron bands shortly after the beginning of the War.

The Germans used the soft iron bands as standard material in calibers of over 8". They were used in some Italian and Czech ammunition in smaller sizes. The use of the soft iron band in high velocity guns was in the experimental stage. In general, however, the Germans preferred to use pre-engraved bands made of soft iron for high velocity projectiles. They also used soft iron as longitudinal inlays in large size projectiles.

For soft iron rotating bands, the Germans used an "Armco Iron" type of material which was treated with a combination of critical cold stretching and low temperature annealing (1250° F.) which produced a large grain size and low tensile properties. The yield strength of the German band was in the range of 7 to 12 kg./sq. mm. and the tensile strength in the range of 24 - 28 kg./sq.mm. It has been suggested by some of the German metallurgists that the production of a large gain size through high temperature annealing (2000° F.) would be as effective as the combination of cold stretching and low temperature anneal. It has been suggested that chromate treated zinc coatings on the soft iron projectiles would improve the performance of the soft iron bands.

Firing test results indicate that the soft iron bands are as satisfactory as copper-steel bi-metallic bands. However, they do not appear to be as satisfactory as the sintered iron bands in guns of normal velocity.

It is believed that this report represents a reasonably adequate picture of the German method of production of soft iron bands and of their results of proof firing. However, no information on design details was available.

Recommendations for Further Work:

1. - It is recommended that steps be taken to obtain the details of rotating band profile and of the rotating band seat as used by the Germans. Notes on some of the projectiles that have been designed for the use of the soft iron rotating bands are included in the section of design factors.

2. - It is recommended that a comprehensive firing test be carried out using soft iron bands designed in accordance with the information obtained in recommendation #1. These bands should be prepared in accordance with the German methods of manufacture.

3. - It is recommended that the bands required for the firing tests be prepared by a development laboratory in order that they be prepared under closely uniform conditions and that all physical test data possible may be accumulated.

4. - It is recommended that studies be undertaken to determine the aging and cold-working characteristics of various types of soft iron of the "Armco" type. The aging characteristics of soft iron bands will be most important in consideration of ammunition being stored for long times.

5. - It is recommended that this study be carried out by an independent development laboratory to insure complete evaluation of the product of various steel producers.

Because of the possibility that additional information, which was not available for the compilation of this report may be available to the Ordnance Department, it is not believed that attempts to outline a complete investigation program on soft iron bands is warranted at this time. Such a program should be outlined only after the information presented in this report has been considered in connection with any other information that may have been obtained.

Respectfully submitted,

SAM TOUR & CO., INC.

By: Sam Tour

Sam Tour,
President.

ST:TR

Appendix "A"

Report No. 8

REPORT OF FIRING TESTS WITH SOFT IRON ROTATING BANDS

According to Proposals by

THE KAISER WILHELM INSTITUT FUER EISENFORSCHUNG

DÜSSILDORF

(FE W-ROTATING BANDS)

In the committee of the Reichs Secretary for research and development for armament and ammunition, it has been decided in the meetings of April 3 and 18 of this year, to carry out an accuracy life fire test, with soft iron rotating bands, by F.H.Gr. of the 1 .F.H.18 (F E W); the rotating bands have been made very soft by critical stretching and annealing treatment, according to proposals of the Kaiser-Wilhelm-Institut fuer Eisenforschung, Duesseldorf.

As basis for the constructive development of this band, use was made of Wa Prüf/(VII) in combination with low carbon iron rings (Karbomin-Eisenfuhrungen) developed by the Bochumer Verein.

The order to produce 10,000 rotating bands for testing, was taken by the Vereinigte Metallwerke, Branch Basse & Selve, Altena Westphalia. As raw material a soft iron has been chosen. This has been supplied up to now by the Bochumer Verein, for KPS-guides. The necessary drawing and annealing treatments were performed in the Linscheid branch of the mentioned firm. Tests of these rings showed a Brinell hardness of 66 to 69, and a yield point between 7 and 9 kg/mm^2. The attaching of the rotating bands to the projectiles was done by the projectile factory of the Bochumer Verein, Bochum, using simple stamping equipment, such as is used for K P S and copper rings.

During the tests it has been shown, that the 45° slot in the rings should be placed parallel to the axes of the projectiles. This facilitates production, without being detrimental to performance.

Preliminary firing of 200 rings served to check the chosen profile, with reference to durability and ballistic standards. The profiles, with several lubricating grooves resulted in great wear and tear; therefore it was decided to produce a profile with only one lubricating groove. The grooves have been filled with Tugra lubricant, developed by Skoda.

The accuracy life test with l.F.H.18 barrel No. 645, took place during June 11th and 26th, of this year, on the artillery range at Unterlies, according to a firing program specified by Wa Pruf 1, which was in conformity with the requirements of the troops. After firing from 500 to 700 shots daily, the ballistics factors have been evaluated by V_0 measurements and accuracy.

The essential result of the accuracy life test is, that after a total number of rounds of 6399 firings, the **barrel is still serviceable** for use in the field.

The following observations have been **made and facts have** been obtained:

1.) The decrease of initial velocity was 1% in the range of large charge, and about 5% in the range of small charge.

These are permissible limits, for a corresponding number of firings for copper rings.

2.) The variations of range of firing table facts were, as far as could be ascertained by preliminary evaluations within admissable limits, so that it can be expected that firing can continue with the same firing table used with K P S guides.

3.) The recording target of firing showed generally a greater dispersion than given in the firing table, but still within the allowable limits. Increasing number of rounds did not essentially impair the recording target.

4.) Wear and tear of the barrel, measured between the lands, was 1/10 mm. (with reference to the Ø), very small for firing up to 6,000, and increased during the test up to 0.15 mm. Consequently this is not higher than wear and tear observed with the K P S guides.

5.) All recovered fired projectiles confirmed the fact of the preliminary firing, that the durability of the bands satisfy the expected requirements.

6.) The forcing cone started a local pinching of the lands, even after 100 firings, as can be seen in the enclosed pictures,* (picture 1 & 2), after 1,505 firings. The ballistic factor was not influenced hereby. The graduation which was formed at the beginning of the land, after 2,230 firings, has been smoothed by re-touching. The graduation did not form to the same extent during further firing (see picture 3 and 4) after 4,953 firings.

7.) Iron deposits have been forming in the front part of the barrel (toward the muzzle), after several hundred firings, first in the lands, later on the grooves, similar to the copper deposits of copper rotating bands. Picture 5 shows these deposits after 2,500 firings, near the muzzle, and picture 6 after 4,953 firings, 500 mm from the muzzle.

* Note: The photographs referred to were not obtained with the original German document.

These deposits in the grooves cause the very cleanly cut land profile, (picture 7 after 12 firings), to be blotted out by increasing number of rounds; (picture 8 after 3,207 firings, and picture 9 after 5,731 firings). The amount of the deposit varies during firing; (see clear profile in picture 9 contrary to picture 8).

Although no detrimental effect has been noticed, so far as the ballistic factor is concerned (compare point 1 to 3), the appearance of rotating bands in recovered projectiles shows, a very great overload and wear and tear, which under certain conditions can cause shearing of the rotating bands, and unsatisfactory drift.

In order to overcome these observed defects, the following procautions for further tests were taken:

a.) The mentioned pinching in the forcing cone, is probably caused by an unfavorable profile formation of the rotating band. To modify this the front cone of the rotating band has been flattened, and the lubricating groove placed to the front as much as possible. In a second test barrel of 1 F.H.18 No. 4975, 276 projectiles have been fired with the unchanged profile of the rotating band. Pinchings at the forcing cone have not been observed so far.

b.) While it is possible, in the case of copper guides, as mentioned in point 7, to eliminate the metal deposits by adding lead to cartridge charges, it still has to be found out by further tests, whether this can be successfully overcome in the case of soft iron guides. In addition the following precautions seem to be in order, to eliminate the deposits:

1.) Further change in the ring profile, to facilitate pressing in the grooves, by a cavity between the ring and the projectile.

2.) Improving of sliding properties by application of low melting metals (zinc), upon the surface of the rotating band. Measures to test this experiment have been started.

Tests with rings for larger calibers (15 cm. and 21 cm.) are prepared.

The results obtained so far by tests with soft iron guides (F E W) are summarized, that if necessary, in the case of these rotating bands, a usable substitute for K P S rotating bands, has been found, but it is desirable to eliminate the existing defects by further tests in the direction of mentioned possible improvements, and to produce a perfect substitute.

For Wa Pruf 1

(Signed) M E Y E R

Chairman of the experimental
co-operative for rotating band
problems with the Reich Secretary
for armament and ammunition.
(Signature illegible)

REFERENCE LIST

Report No. 8

*60. O.T.I.B. Item 2553. Letter Dip. Ingr. Kallima to Reich Secretary for Arms and Ammunition, Prague, December 16, 1940.

*61. O.T.I.B. Item 2535. Letter. Prof. Korber, Kaiser Wilhelm Institute to Dr. Garbotz, Representative of Reich Secretary for Arms and Ammunition. Dusseldorf, May 2, 1941.

*62. O.T.I.B. Item 2551. Report of Discussion with Skoda Firm at Pilsen. January 14, 1941.

*63. O.T.I.B. Item 2532. Report on Test Firing of Soft Iron Rotating Bands. Undated.

*64. Report No. 42 on Annealing Tests on Armco-Iron Rotating Bands. October 7, 1941.

*65. Report No. 30 on Annealing Tests on Armco-Iron Rotating Bands. June 16, 1941.

*66. O.T.I.B. Item 2552. Letter to Representative of Reich Secretary for Arms and Ammunition. Duesseldorf. January 3, 1941.

* All of the above documents were translated from the original German documents.

\# See Vol 6. of file.