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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 342

IDENTIFICATION OF AIRCRAFT TUBING BY ROCKWELL TEST

By Horace Knerr

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IDENTIFICATION OF AIRCRAFT TUBING BY ROCKWELL TEST.

By Horace C. Knerr.*

Seamless steel tubing is to-day the principal material of construction for aircraft. The commercial grade of tubing containing about 0.10 to 0.20% carbon at first used is being superseded by two grades which are approved by the army and navy, and which are also becoming standard for commercial airplanes, whose composition is given below:

Steel #1025 straight carbon	
Carbon	.20-.30
Manganese	.50-.80
Phosphorus max.	.045
Sulphur max.	.05

Steel #4130X chrome molybdenum	
Carbon	.25-.35
Manganese	.40-.60
Phosphorus max.	.04
Sulphur max.	.045
Chromium	.80-1.10
Molybdenum	.15-.25

(A 3½% nickel steel was formerly employed in aircraft construction, where high strength was required, but this is being abandoned in favor of chrome molybdenum steel because of the superior characteristics of the latter.)

The physical properties of the two standard steels, in the normalized condition, are as follows:

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*President, Metallurgical Laboratories, Inc.; Consulting Metallurgical Engineer, Summerill Tubing Company.

Steel #1025 straight carbon		Steel #4130X chrome molybdenum	
Yield point (min.) ...	36,000	Yield point (min.).....	60,000
Tensile strength	55,000	Tensile strength	95,000
Elongation in 2"	22%	Elongation in 2"	12%

The above properties are minimum values and are ordinarily considerably exceeded. Steel #4130X can, by heat treatment consisting of quenching in oil from about 1600°F., followed by suitable tempering, be given extremely good physical properties such as are shown in following table:

<u>Physical properties</u> - Pounds per square inch

Tensile strength	125,000	150,000	175,000	200,000
Yield point	110,000	130,000	140,000	150,000
Elongation in 2"	11%	9%	7%	5%

Axles, landing gears, wing beams, and other parts requiring high strength are made of chrome molybdenum steel heat-treated after assembly. The major part of both types of steel is used in the construction of airplane fuselages assembled by welding As it is ordinarily impracticable to heat-treat an assembled fuselage, design factors are based on the strength of the tubing in the normalized condition. Most aircraft builders prefer to have the mild carbon steel in a slightly harder state than results from normalizing, and it is moderately tempered by the tube mill after cold drawing, so that it has a tensile strength in the neighborhood of 60,000 to 65,000 pounds per square inch. The chrome molybdenum tube is, however, normalized by the tubing manufacturer. This treatment consists in heating it to 1600°F.

and allowing it to cool with free circulation of air.

In spite of the greatest care, there is danger that an occasional tube of #1025 steel may become mixed with a quantity of #4130X steel, in the tube mill, or in the aircraft manufacturer's plant. If such a tube entered into construction where design called for chrome molybdenum tube, either normalized or heat-treated, there would be serious risk due to its inferior strength. It is therefore important to guard against such admixture.

In the tube mill, the problem is a difficult one. It requires the testing daily of thousands of pieces of tube, varying in length from 10 to 20 feet, but averaging about 12 to 15 feet; varying in diameter from 1/4 to 4 inches; varying in wall thickness from .0015 to 3/8 inch, and varying in shape from round to streamline, elliptical, square, and other special forms. It is of course impracticable to make a tensile test on each piece. No chemical test, even of a qualitative nature, is available for the ready and rapid identification of chrome molybdenum steel. One or two tests which have been developed are not positive under all circumstances and require too much time and attention to be practicable in the inspection department of a tube mill. Magnetic tests have possibilities, but require relatively costly equipment, and are subject to certain limitations. A hardness test appears to be the most desirable from the standpoint of simplicity, speed, and dependability. Neither Brinell tests nor Scleroscope hardness tests can be applied to thin-walled tubing. The Rockwell hardness test seemed to offer promise and was accordingly investigated.

A large number of tests were made on tubes of #1025 and #4130X steel, in various diameters and wall thicknesses, and after diverse heat treatments. The Rockwell B scale was employed, as being best suited to the ranges of hardness encountered. It was found that the Rockwell hardness did not bear any direct relation to the tensile strength of the tubing, and it was also found that the hardness ranges of the two types of tubing in the "as drawn" condition, overlapped. However, after normalizing, there was found to be a distinct gap between the Rockwell B hardness of #1025 steel and that of #4130X steel. While each varied in hardness within fairly wide limits, no carbon steel showed a hardness in excess of 80-B and no chrome molybdenum steel showed a hardness less than 90-B, with the exception of a few pieces. The latter, under the test, were laid aside as doubtful. Only satisfactory chrome molybdenum tubes were found to show a hardness in excess of 90-B after normalizing. The method therefore provided the desired means of identification of chrome molybdenum steel. It is a qualitative test only.

The conditions of satisfactory test are as follows:

a) The tubing must be normalized as above described.

b) It must be clean inside and out at the point where the test is to be made, to insure the removal of dirt and scale, and present a smooth bright surface.

c) The tube must be held in correct alignment with the penetrator and must not move during the test. (A permanent movement of 0.0001 inch affects the reading.)

d) For thin-walled tubes, the anvil must extend within the tube so as to support the wall.

It was found that, on tubes having a wall thickness less than .035 inch, it was necessary to apply a correction factor to the reading, owing to the effect of the anvil. This, however, in no way interferes with the distinction between the two grades of steel. Certain anvils also require the use of a correction factor such as the addition of about 2 points to the reading, because of the indentation made by anvils of small diameter on the inner wall of small tubes.

Because of the great difficulty in holding tubes of long and varying lengths in correct alignment with the Rockwell penetrator, it was at first necessary to cut off a short length from the end of each tube, to number the tube and the end thereof, correspondingly, and to take readings on these small rings. Both the tube and the ring were given the same normalizing treatment. This entailed a large amount of labor in the cutting off and numbering of the tubes, the latter being done by means of steel stencils. In order to eliminate this excess labor and speed up the inspection of large quantities of tubing, a machine was designed* to handle the various sizes of tubing and hold them in correct alignment. (Figures 1, 2, 3). The machine was provided with a cleaning apparatus to prepare the ends of the tubes for the Rockwell test. This apparatus consisted of an emery belt for cleaning the outer surface over a suitable small arc and at the same time, cleaning the inner surface over a corresponding arc. The inner surface is cleaned by means of a rotating file while the emery belt cleans the outer surface (Figure 4). This part of the work is done by one operator, who then loads the tubes on a set of conveyor chains by which they are transferred across the machine to the other operator who takes Rockwell readings. The two operators readily keep pace with each other, but if there is a difference in their speed of operation, or if it is desired to conduct the test with only a single operator when the quantity of work is not great, a batch of tubes can first be cleaned and placed on the conveyor chains, whereupon the operator takes his position at the other side of the machine, and makes the Rockwell readings, moving the prepared tubes toward him by means of a hand lever which operates the conveyor chains. To provide for testing tubes of various diameters the machine was designed so as to align the tubes with the Rockwell penetrator by means of a guide at their <u>upper</u> surface. In other words, the tubes are pressed upward against the lower surface of a straight edge which is correctly aligned with the penetrator. Provision is made for accurate

*Designed by Andrew King, Consulting Mechanical Engineer, and the writer.

adjustment between the penetrator and the straight-edge guide. Special anvils were designed having a cylindrical member horizontally mounted and extending into the tube axially about 1/4 to 1/2 inch, thereby giving a line support for the inside surface beneath the penetrator. It is necessary that the axis of the cylindrical support be accurately parallel with the axis of the tube. An adjustable guide rod extending from the anvil into a vertical slot attached to the machines takes care of this. It was found necessary, because of very slight deviations in straightness and other irregularities to clamp the ends of the tubes tightly against the supporting cylinder in order that the tube and cylinder be solidly in contact before taking a reading. The anvil is therefore provided with a clamping device operated by a small hand lever as shown in Figures 5 and 6.

Anvils of two sizes were found to be adequate to take care of a wide variation of diameters and thicknesses of tubes. One of these has a supporting cylinder 1/8 inch in diameter and 3/8 inch long, and the other 1/2 inch in diameter and 5/8 inch long. The anvils are interchangeable with the regular anvils of the Rockwell machine.

The first operator brings the tube to proper position between the belt and the rotating file by hand, then brings the belt down upon the tube by means of a foot pedal. Ordinary round files are used for cleaning the inside surface, a half-inch file being used for large tubes, and one-eighth inch file for very small tubes. The files are broken into short lengths of about 2 inches and the pieces are held in a drill chuck, which is rotated by the same motor which drives the emery belt. Files and belts are renewed from time to time. A hood and exhaust remove the dust and filings.

The second operator, who takes the hardness readings, moves the tubes toward himself as required, by means of a hand lever and rachet which operates the conveyor chains. The tube is allowed to fall upon a series of fingers, whereupon it rolls under the straight edge and is then brought up against the latter by means of a foot pedal.(Figures 1 and 2). After taking the reading, a further movement of the foot pedal discharges the tube upon a waiting truck.

This method and apparatus have been in operation for approximately two years at one manufacturer's plant, and many hundreds of thousands of feet of tubing have been tested. In no case has a mild carbon steel tube been allowed to pass except in a very few instances which were traceable directly to the carelessness of the operator. To take care of the increased production, a second machine has been constructed, similar to the first one, and has been in use for about six months.

May, 1930.

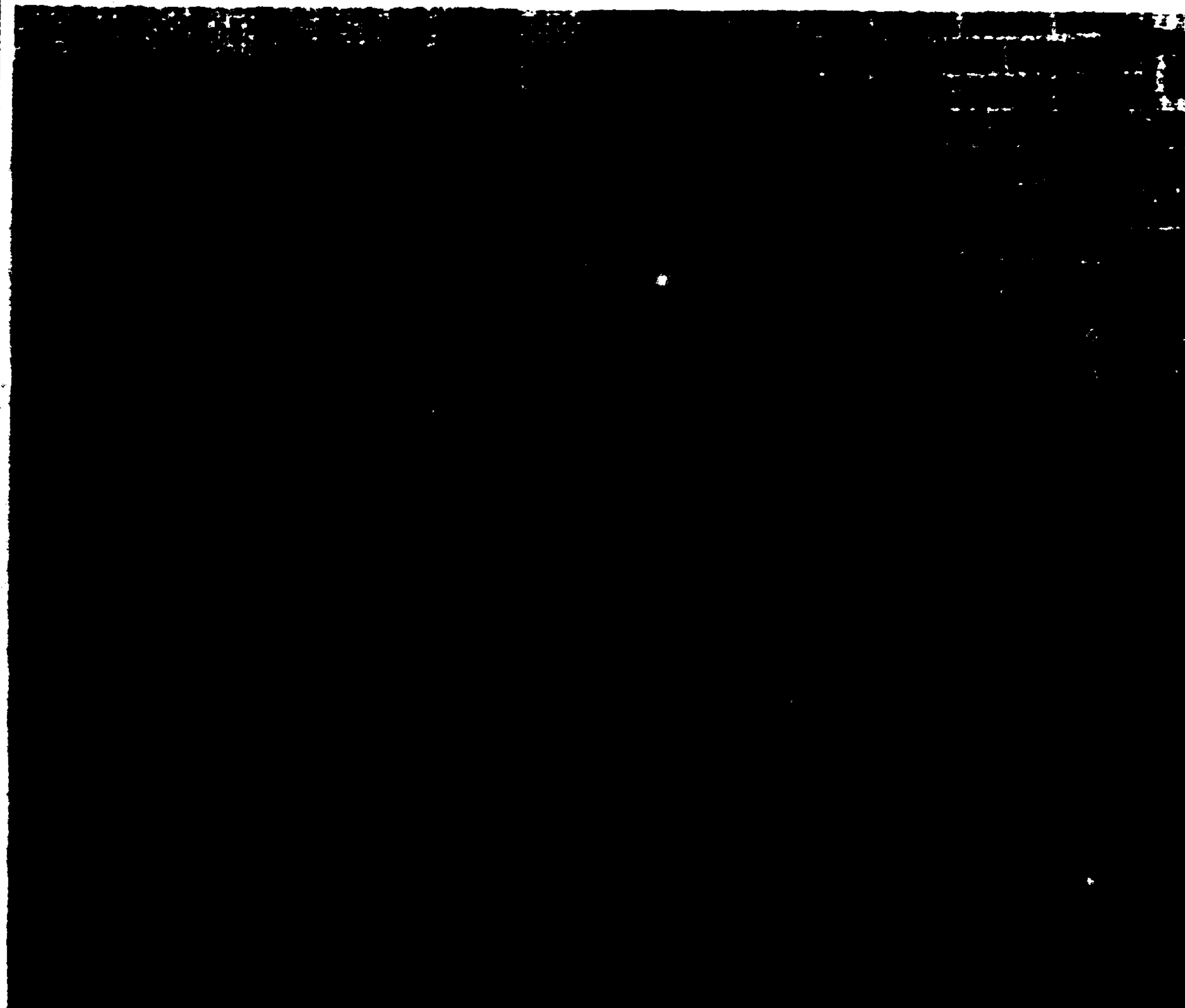

Fig.2

Fig.3

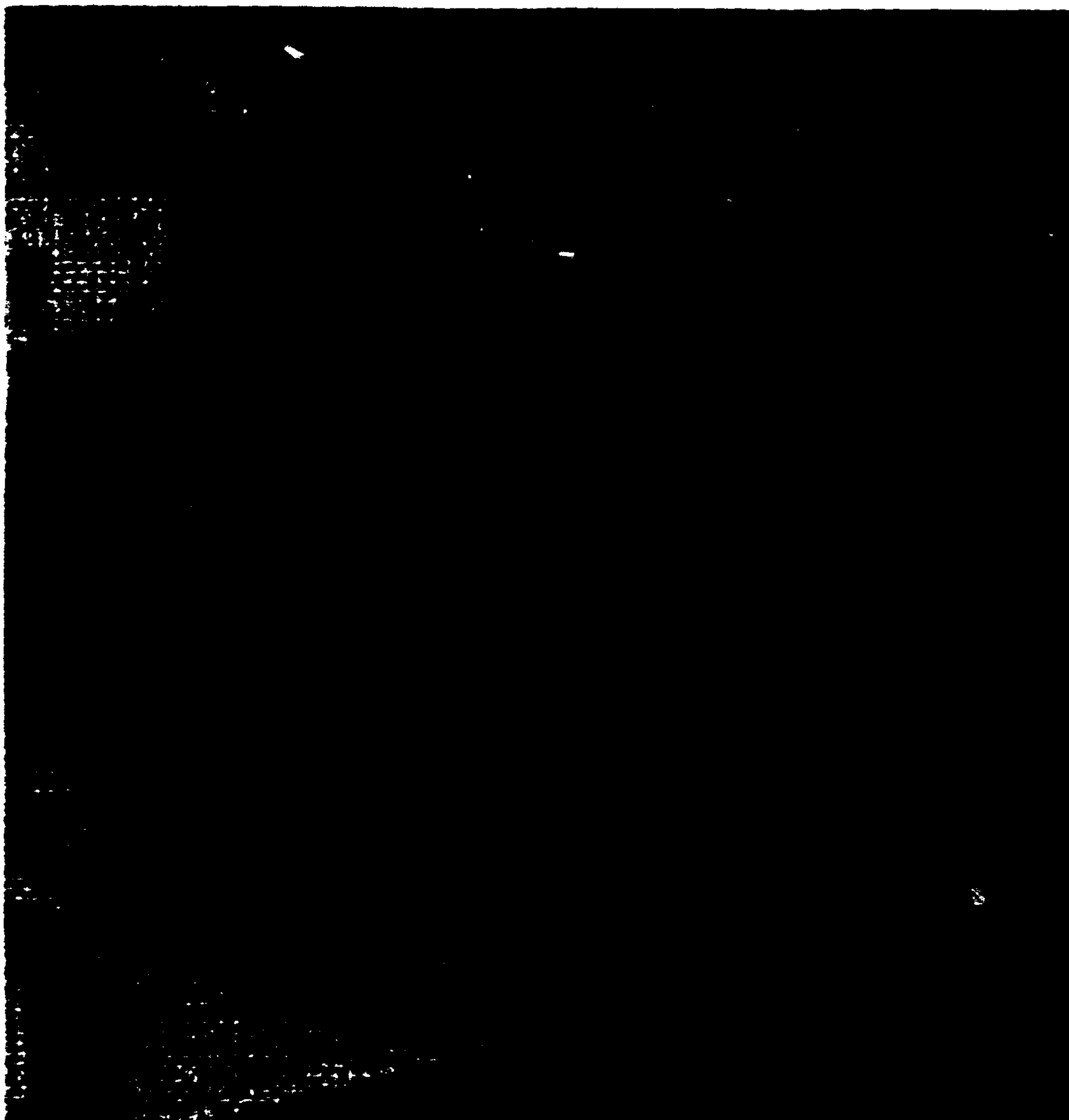

Fig.5

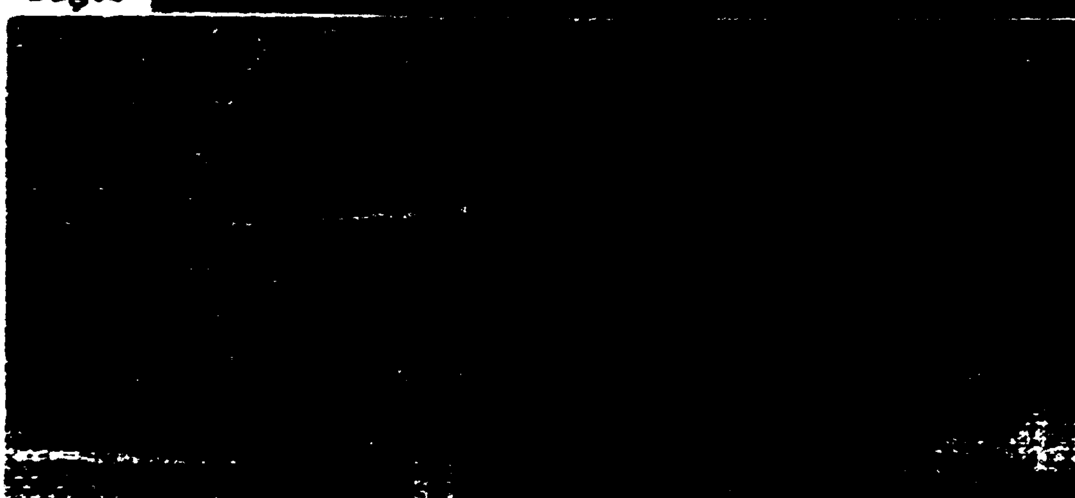

Fig.6

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