Bundy Tubes

Application Report

PRÜFTECHNIK AG

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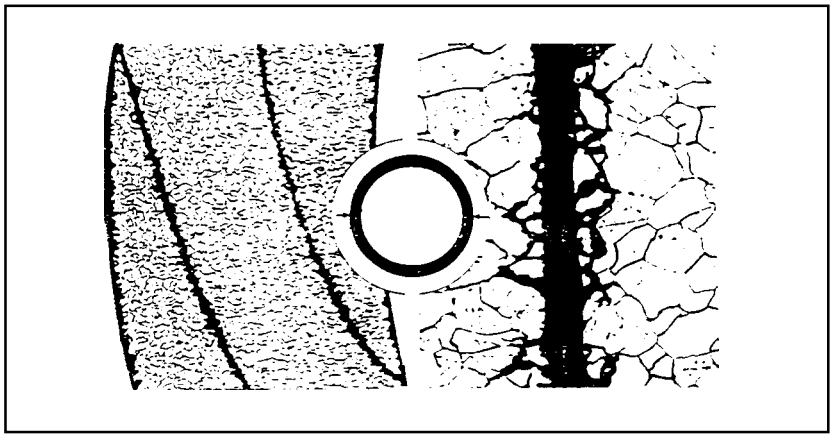
Introduction

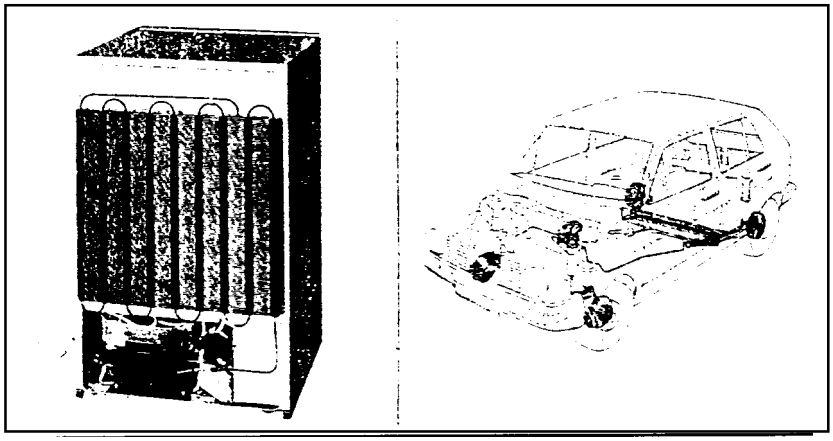
Bundy tubes are double walled, rolled and brazed tubes which meet the highest specifications.



The bevelled seam edge of Bundyweld provides smooth joints and eliminates inside and outside beads.

The copper bonds with the steel alloy due to 360° wall contact. Thus, it can resist vibration fatigue and withstand high pressures.

Due to the type of manufacture the tubes are almost guaranteed leakproof and are also suitable for very high pressures (>1000 bar). As a result, the main application areas are the refrigerator industry and, above all, the automobile industry where they are used wherever operational safety plays a major role such as for heat exchangers in air conditioners, for oil and fuel lines and, most importantly, for brake lines.

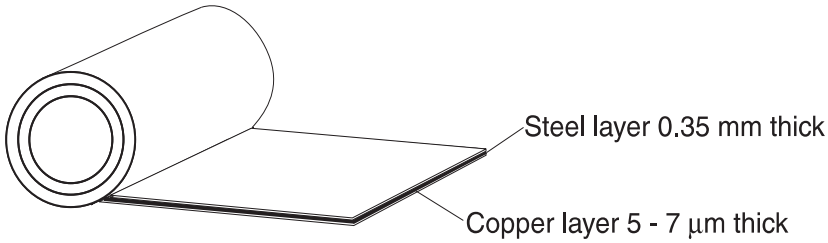


The processing industry increasingly requires the guarantee of consistently high quality. This applies to the automobile industry in Germany, for example, which requires that the `human factor´ is minimised. That is to say that all decisions are reached automatically. This places a high requirement on the reliability of the test systems in which the defect recognition and sorting take place automatically.

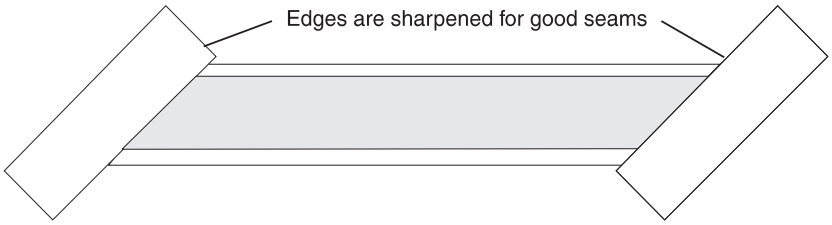
The automatization enables the user to save on personnel and thus wage costs.

Production

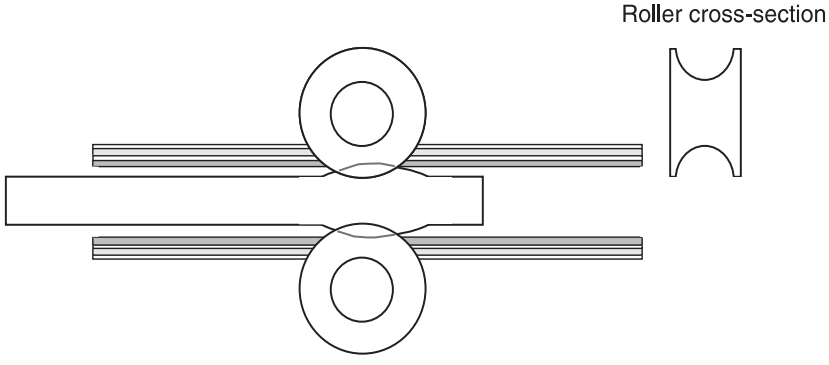
The initial material is a steel band with a pure (99.99%) copper coating. The steel is 0.35 mm thick and the copper coating is approx. 5 - 7 µm.



The band is cleaned in-line and oiled. The edges are sharpened with the aid of two pressure rollers in order to obtain a good internal and external seam.

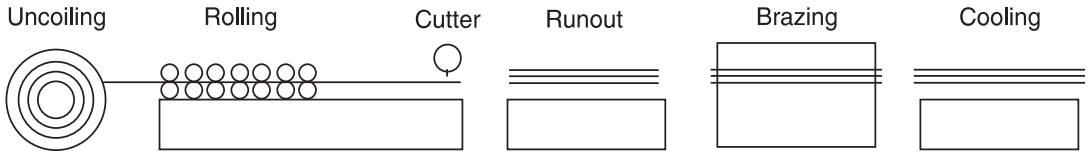


The tube is shaped by several roll stands. The last stand determines the final diameter and the roundness of the tubes. At that position there is a swimmer in the inside of the tube with two heads. The swimmer presses the wall of the tube against the last two rollers. The position of the swimmer determines the winding thickness which in small diameters correlates directly with the quality or number of cavities between the layers of the tube walls.



In order to compensate for the ‘waviness´ which can arise from the mechanical processing of the band, the speeds of the rollers are controlled so that the tube is continuously drawn. The stretching factor amounts to approx. 1.04 - 1.08.

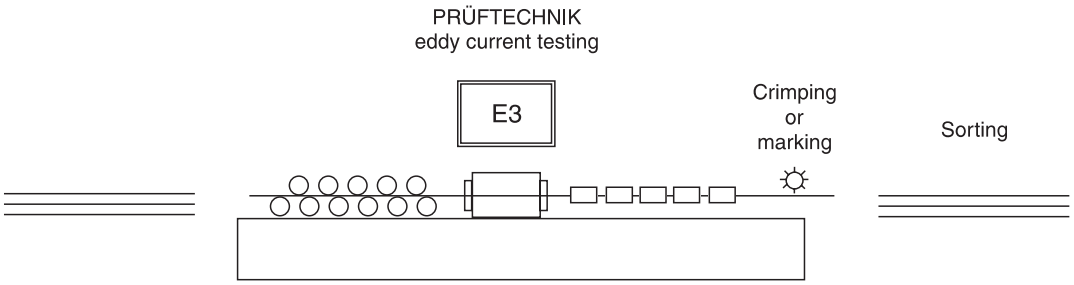
The wound tubes are collected together and then fed through a brazing furnace in batches (30 - 40 pieces) and are brazed at approx. 1090° (copper melts at 1078°). Due to the slow speed and the precisely controlled temperature range, a very homogenous brazed tube results. It is then air-cooled in the cooling area.



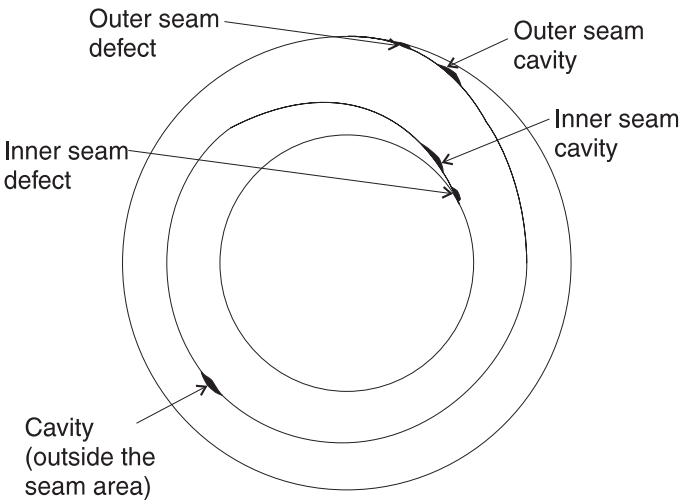
Quality Control after Brazing

The brazed tubes are tested off-line using the EDDYCHEK 3 and sorted into up to 4 classes. The testing is carried out between the horizontal and vertical straightening devices to ensure reliable and disturbance-free testing.

In addition, samples of the ends of the tubes are taken for mechanical testing using crushing and expanding testing.



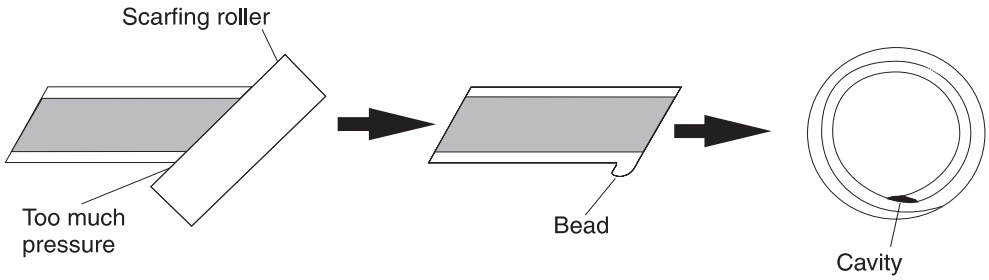
Typical Defects



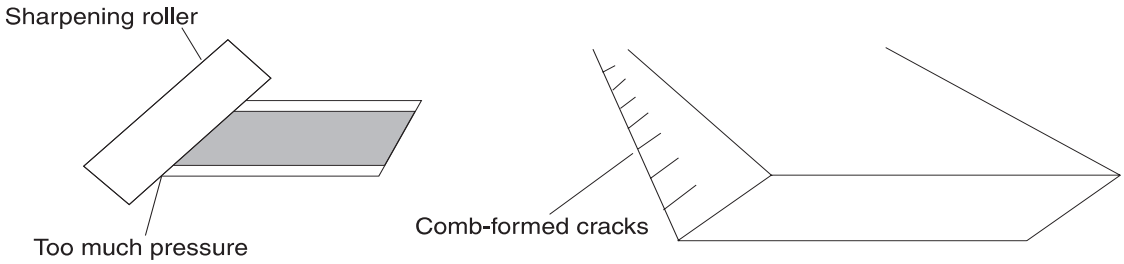
Causes of Defects in Sharpening

- **Cold forming**

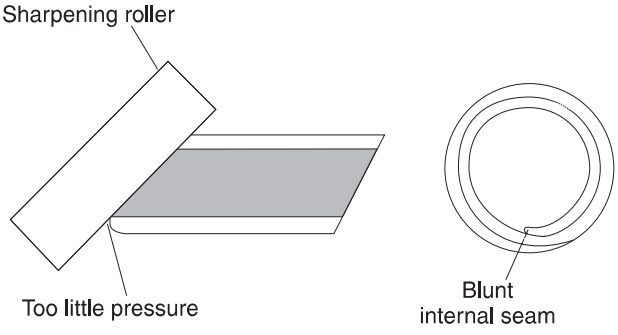
A bead can result which can lead to holes after forming.



- **Comb-formed cracks**

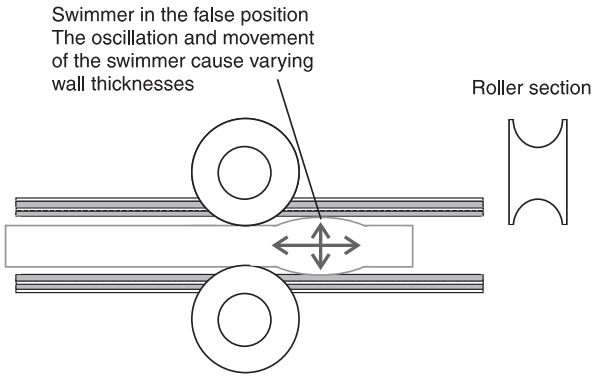


- **Butted external seam**



- **Incorrect swimmer position**

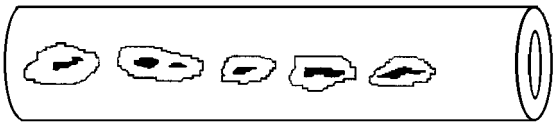
If the swimmer sits too far back, the winding pressure is too low and leads to holes.
If the swimmer is too far forward, the pressing force is too high and the swimmer begins to oscillate. This leads to an oscillating winding thickness.



In the Oven

- **Copper spots**

The copper has melted and has become concentrated.



- **Copper runs**

Similar to copper spots - the copper has melted and the surface has become uneven.

The Effects of Different Types of Defect

Holes away from the seam area do not lead to leaky tubes since even completely unbrazed tubes are leakproof if they are well wound but they do lead to defects on the flanges so that the tube connections are no longer leakproof.

All errors within the seam area (internal and external) are critical and lead to a reduction of the burst rating of the tube.

Copper spots or copper runs are not really tube defects. However, the copper spots are dressed by a drawing die and copper spots that are too large result in damage to the opposite side.

Although the signals cause by copper spots can be suppressed using sector evaluation, accumulations of copper spread over a large area always lead to false outputs as the directions of the signals vary and can fall within the region of the external seam defect.

Test Setup in EDDYCHEK 3

The eddycurrent testing takes place off-line following the brazing. The test speed is about 4m/s and the length of the tubes 32 metres. The temperature difference between the two ends of the tubes is up to 20° and must be taken into account when setting up the absolute channel.

Since the tubes are ferritic, magnetic saturation is necessary. The testing yoke with an encircling coil is located between two straightening rollers which should ensure the least vibration possible and, as a result, trouble-free running.

Following the testing the larger defects are mechanically marked (crimped) so that, even after plastic coating, the marked positions can still be identified and therefore sorted.

The tubes are classified into up to 4 sort classes and sorted accordingly:

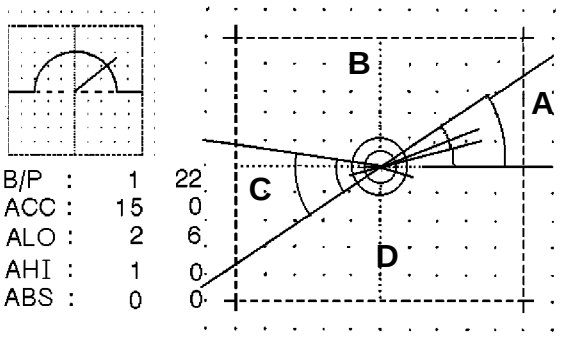
Good:	no defects or only a few of the smallest defects
A:	ACC - defect density exceeded or only a few small defects (ALO)
B:	A few larger defects (AHI) but parts of the tube are still usable
Scrap:	An absolute defect or so many AHI/ALO defects that the tube cannot be used

For the testing, a differential channel is used as well as an absolute channel for longer unbrazed spots.

Alarm Masks

The alarm masks have four separate areas. Two of them are very sensitively evaluated and the other 2 are for less relevant defects.

A : Copper spots
B : External seam defects, unbrazed tube, cavities (copper that has run outside)
C : Rust particles
D : Internal seam defects, unbrazed tube (copper that has run inside)



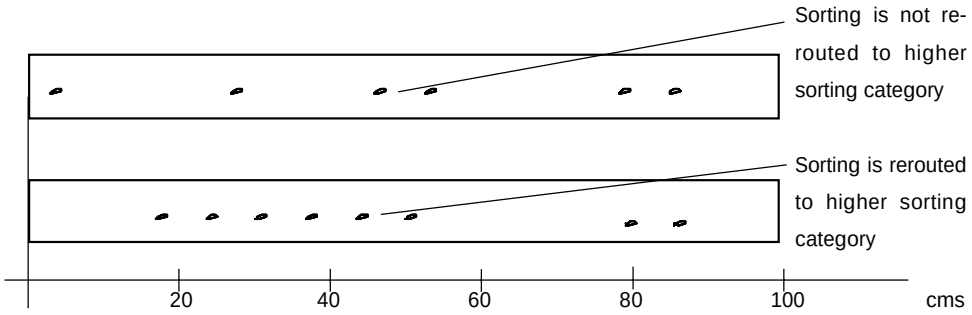
Defect Density

In addition to the counting of defects, the EDDYCHEK 3 monitors the defect density. Two different methods of evaluation are used :-

Evaluation of defect density

The number of ALO or ACC defects allowed within a specified distance is called defect density. If one of the defect densities is exceeded, the tube is sorted as A quality (for ACC defects) or as SCRAP (for ALO defects).

E. g.:-
ACC Reroute Dens. = 6
(or ALO)
ACC Reroute Ref. = 40 cm
(or ALO)



Evaluation of minimum good length and total good length

If there are not too many AHI defects within the tube, it may be economic to cut out the lengths between them and process these lengths further (e.g. in producing smaller individual parts) later in production.

To establish the lengths of these pieces and thus the viability of using them, several parameters can be input independently into the EDDYCHEK 3. These are used to calculate lengths and numbers and types of defects and to evaluate the feasibility of cutting out any useable pieces and whether the quality is good enough to be further processed.

EDDYCHEK 3 Reports

SPC Report

The SPC Report provides a statistical analysis of the test results for each batch.

SPC-REPORT: Inspect. 2 (3200/475) 26.05.93, 14:52 Page 1
EDDYCHEK3 Rev 2.4-0018E

STATISTICAL PROCESS CONTROL

Batch	S0 (-G-)	S1 (-A-)	S2 (-B-)	S3 (-S-)	SUM	Date & Time
1	21 679m	1 32m	3 97m	5 162m	30 970m	26.05 14:42
2	24 777m	4 132m	1 32m	1 36m	30 977m	26.05 14:45
3	26 834m	1 31m	2 65m	1 32m	30 962m	26.05 14:48
4	24 775m	4 125m	1 34m	1 32m	30 966m	26.05 14:51
Total	95	10	7	8	120	26.05 14:51
Length	3065m	320m	228m	262m	3875m	SHIFT-END

Example

Batch 3 in the example above consists of:

- 26 test pieces of good quality with a joint length of 834 m
- 1 test piece of `A´ quality with a length of 31 m
- 2 test pieces of `B´ quality with a joint length of 65 m
- 1 test piece of scrap quality with a length of 32 m.

This gives a total number of 30 pieces with a combined length of 962 m. The batch was tested on 26.05.93 at 14:48.

Defect Location Report

The Defect Location Report provides a printout of the defects found together with their locations on the test piece for each test piece in a batch.

```
DEFECT-LOCATION REPORT:  Inspect. 2     (3200/475)     26.05.93, 14:56   Page   1
                                                       EDDYCHEK3 Rev 2.4-0018E

Batch completed  26.05.93, 14:56

Sorting-Class  | S0  (Good)  | S1  (- A -) | S2  (- B -) | S3  (Scrap) || Sum= |
BATCH:  1      |   25 / 83%  |    2 / 7%   |    2 / 7%   |    1 / 3%   ||   30 |
Length / [m]   |  814 / 83%  |   65 / 7%   |   64 / 7%   |   32 / 3%   ||  975 |

Part-Number, Coil, Sort-Class   [  Alarms: ABS=#, AHI=*, ALO=o  ]   Length / cm

25   A s1|-----------------------------------------o-----------o--------|3259

15   A s2|--------------------*-*---o-----*-o-oo-o-----o-o----o----------|3158

8    A s3|-----------##########*-o-------------------------------------|3215
7    A s1|----------------o---o-----------------------------------------|3255
4    A s2|----------o---------o-o--o--*-------*---o*----*-o--*--o*-------|3247
```

Example

Part no. 8 in the example above is a test piece of 3215 cm tested by coil A with:

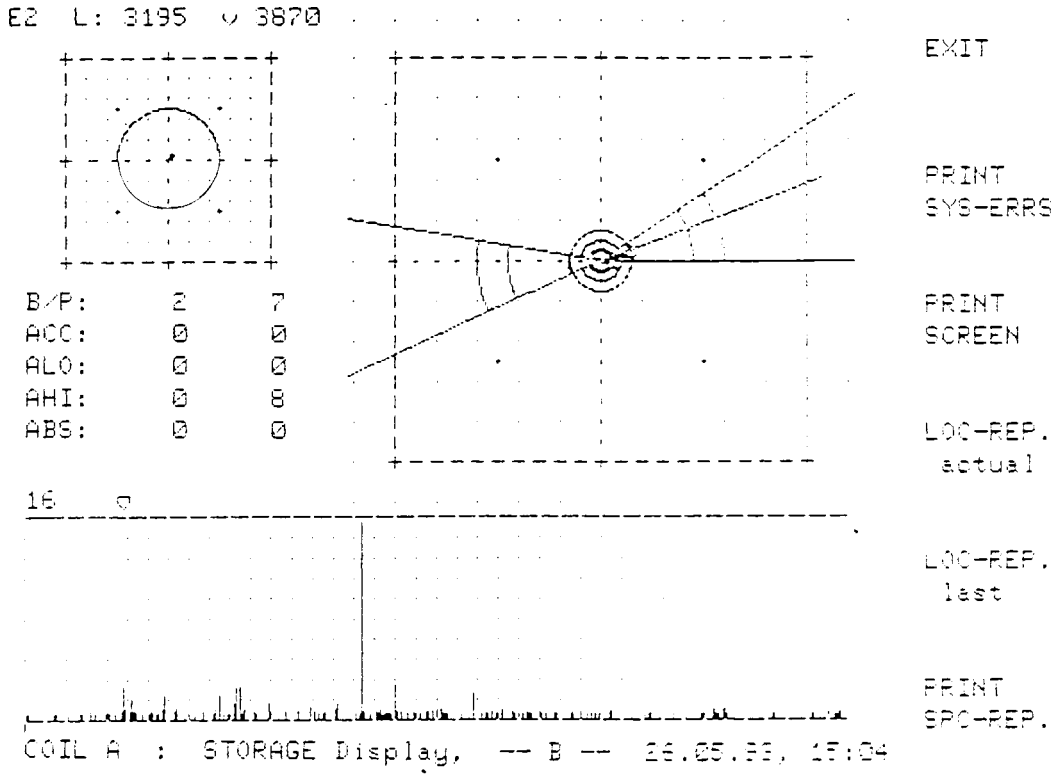
- 10 absolute defects (#)
- 1 AHI defect (*)
- 1 ALO defect (o).

It has a sort class of 3.

The positions of the defects are indicated by the position of the characters on the line.

Print Screen

The printout of the screen is very useful in the creation of a defect catalogue.



WITHOUT ENCODER , Line-Speed mm/sec : 4000

INPUTS (TRUE) Line_Forward [NK0]: LOW Abs_Balance [NK1]: LOW
Mat_Feed [NK6]: LOW Sort_Arrive [NK5]: LOW

GLOBAL PARAMETERS

Low-Pass Filter No. :	9	DV-Storage-Displ. Span cm :	0
R/t-Display Resol. cm/bar :	8	R/t-Marker Threshold % :	12

COIL PARAMETERS

Differential Gain Lo dB :	20	Differential Phase Lo Deg :	95
Differential Gain Hi dB :	0	Differential Phase Hi Deg :	0
Different. HP-Filter No. :	8	Different.Coil Width %mm :	500
Absolute Gain dB :	20	Absolute Phase Deg :	135
Absolute Alarm Level % :	25	Absol. Alarm Sector Deg :	180
Absolute HP-Filter No. :	3		

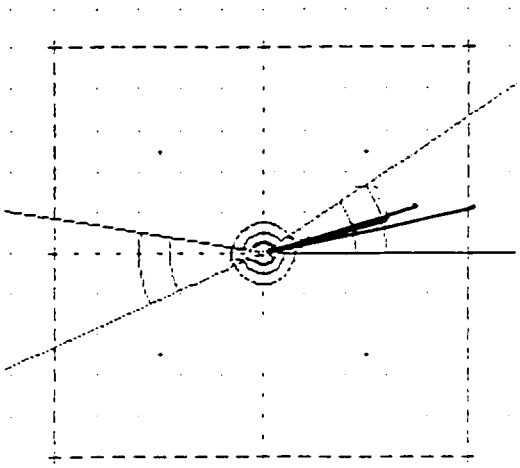
FREQUENCY : f_Lo = 10.0 KHz , f_Hi = 157 KHz (FR-FF29)

REPORT PARAMETERS		Operator No. 0...9999 :	2
Size A 0...9999 :	3200	Size B 0...9999 :	475

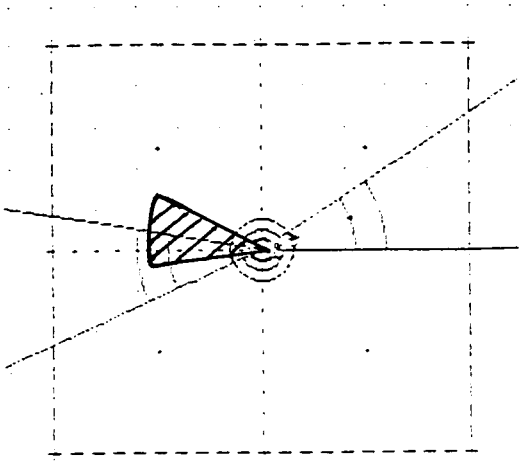
EDDYCHEK3 Rev 2.4-0018E

Defect Catalogue

Copper Spots, copper that has spread to the outside



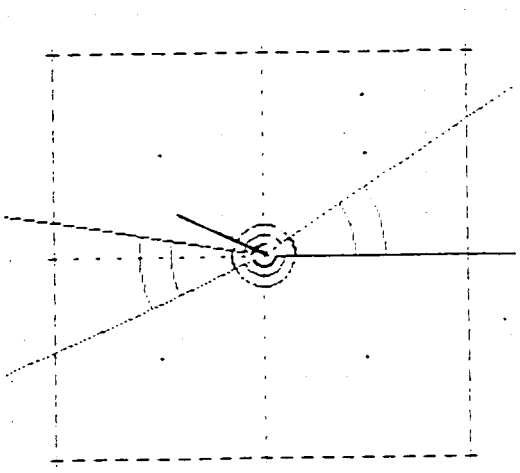
Copper spots

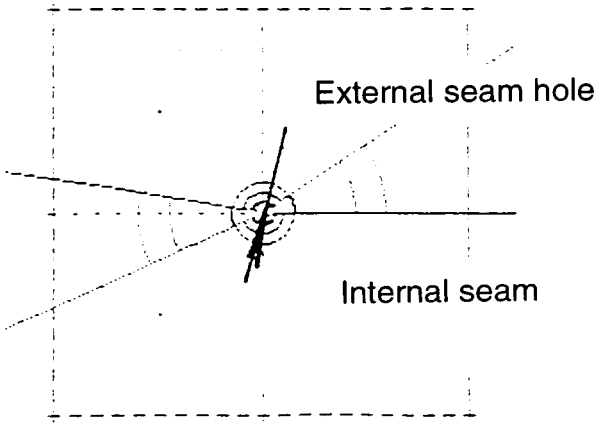


Copper that has spread
to the outside

External Seam Defects (Holes)

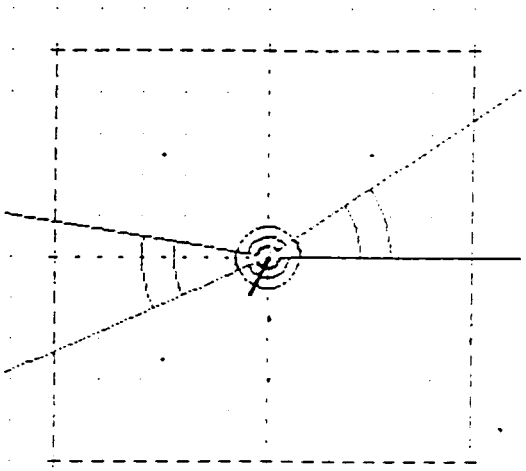
Cavities in the external seam



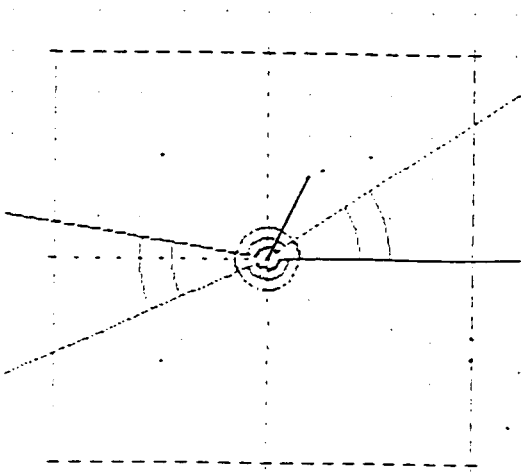


often occur together due
to edge preparation

Internal Seam Defects

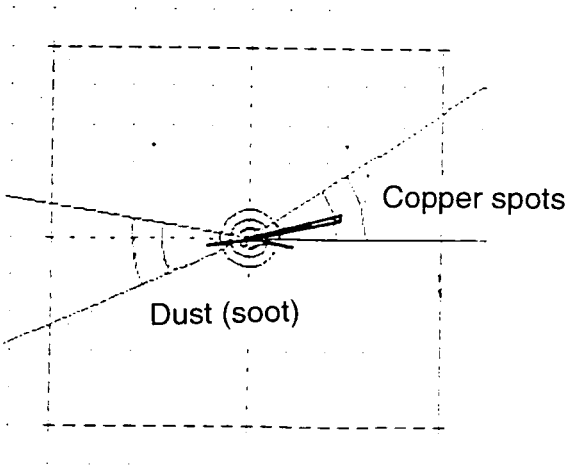


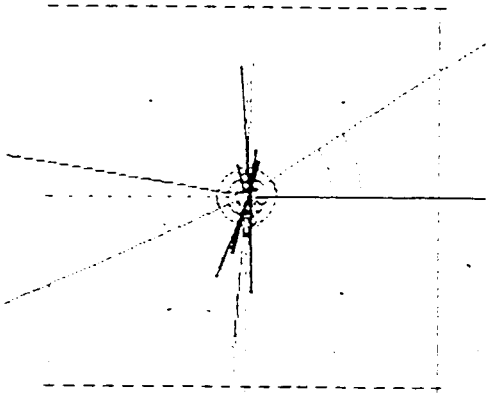
Internal seam defects



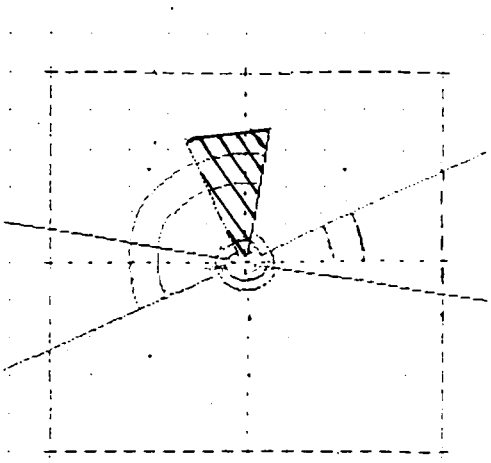
Internal seam cavity

Other Defects





Unbrazed tube



Cavities away from
the seam area