Standard Operating Procedure

Assessment of Hole Enlargement Resistance in Insecticide-Treated Nets (ITNs)

1. Scope

This document describes the method for assessing the hole enlargement resistance in open mesh textile structures such as those used in Insecticide-treated Nets (ITNs). Holes enlarge during use as a result of yarn breakage and tension applied to the fabric. This method assesses the extent to which hole enlargement is resisted.

2. Referenced Documents

The following referenced documents are useful for the application of this document.

ISO 139:2005 Textiles – Standard atmospheres for conditioning and testing.

BS 3424-38:1998 – Testing Coated fabrics. Determination of wounded bursting strength.

ISO 13938-2:1999 Textiles – Bursting properties of fabrics. Pneumatic method for determination of bursting strength and bursting distension.

3. Terminology

Open mesh textile: A textile which due to its inherent structure consists of a large number of closely spaced apertures.

Aperture: An opening in the textile structure larger than 1 mm.

Hole: An opening in a textile which is not part of its inherent structure and is the result of breakage or displacement of yarns.

Hole enlargement: The enlarging of an existing hole in a textile structure as a result of tension applied to the fabric.

Maximum Feret Diameter: The largest diameter defined as the distance between two parallel lines at the extremities of the object that are tangential to the boundary. An example is given in Figure 1.

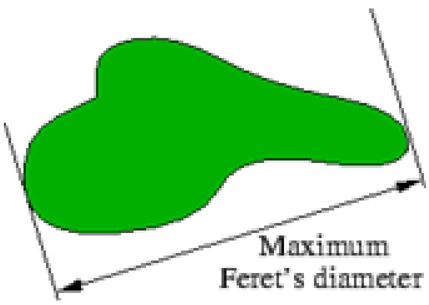

Figure 1 Maximum Feret's diameter.

Secondary failure: Laddering, tearing and unravelling are mechanisms of hole enlargement assessed by visual inspection of the specimen after testing is performed.

Laddering : A ladder or laddering is caused by sequential loop disengagement in a knitted structure. Laddering presents itself as sequential un-looped but unbroken yarns which run parallel throughout the knit structure and it does not form a hole by itself.

Unravelling: Unravelling is caused by sequential loop disengagement in a knitted structure. In unravelling the loops of a knitted structure disengage to create a hole.

Tear: Tear is the tensile breakage of yarns in one or more directions. Tears are usually associated with large hole sizes (> 21 mm).

4. Summary of Test Method

The test specimen is first wounded by cutting yarns to create a hole and cyclic pressure is applied on the wounded specimen to measure the resistance to hole enlargement. After wounding the specimen, the specimen is mounted on a pneumatic bursting strength tester, with a 50 cm^2 circular test area, ensuring that the preformed hole is centrally located above the diaphragm below. The specimen is then exposed to 3 consecutive cycles of loading by partial inflation of the diaphragm, which tensions the specimen according to a set pressure but does not result in yarn breakage. The hole size after tensioning is assessed, as are any secondary failures that occur as a result of the loading, such as laddering, tearing and unravelling.

5. Significance and Use

ITNs are used to form a physical barrier between the user and insect vectors of disease. Any enlargement of holes substantially reduces the barrier protection enabling insects to penetrate the structure leading to the potential transmission of diseases such as malaria.

6. Apparatus and Materials

A pneumatic bursting strength tester is required capable of cyclic loading according to the parameters given in Table 1. Such equipment, is available from the following manufacturer (supplier):

James Heal
Richmond Works
Halifax, HX3 6EP
United Kingdom
(supplier of the TruBurst Pneumatic Bursting Strength Tester).

The bursting strength tester should be fitted with a 1.5 mm thick diaphragm.

Additional items of equipment required are:

- Piece glass or magnifying glass.

- Ruler capable of measuring to 1 mm.

7. Sampling and Test Specimens

Sampling

A total of 5 specimens per ITN sample are tested. The 5 specimens measuring 200 X 200 mm (L X W) are taken from each of the four side panels of the ITN and the roof panel as shown by the areas illustrated in Figure 1.

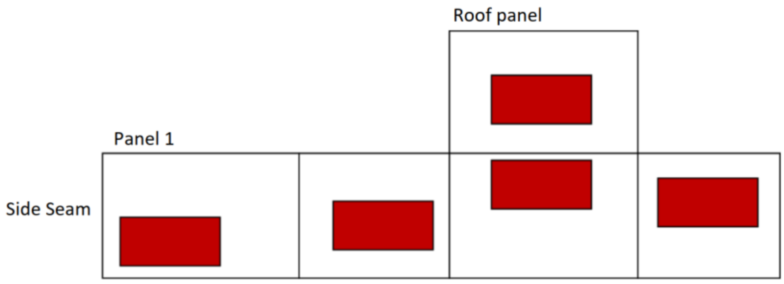

Figure 1 Example of sampling.

A total of 5 specimens per ITN sample are tested. The 5 specimens are taken from each of the four side panels of the ITN and the roof panel as shown by the areas illustrated in Figure 1. A minimum of three different ITN samples is required for testing. A total of 15 specimens are therefore measured. When taking the specimens for testing it is important to ensure that they do not share wale yarns.

Specimens

The fabric test area is a circular specimen of at least 140 mm in diameter. Typically, a square of 200 X 200 mm is utilised for testing.

8. Conditioning

The atmospheres for preconditioning, conditioning and testing are as specified in ISO 139:2005.

9. Procedure

Test programme parameters

ITN hole enlargement resistance testing

The test parameters for ITNs testing are outlined in Table 1.

Table 1 Testing parameters for hole enlargement resistance testing of ITNs.

Bursting test area	50 cm^2
Target Pressure	80 kPa
Inflation rate	15 kPa/s
Number of cycles	3
Time held at target pressure	3 seconds
Relax time between cycles	3 seconds

Preparing specimens

Wounding of ITN specimens

To prepare a warp knitted ITN specimen, one complete unit cell of mesh is cut out and removed. Examples are given in Figures 2 and 3 for two warp knitted fabrics with different knitted structures (A and B). The red dashed lines indicate the cut lines required to remove the mesh section.

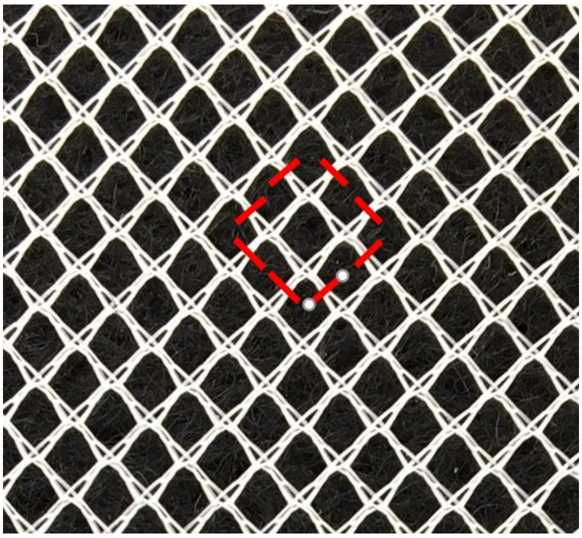

Figure 2 Example of wound position on warp knitted ITN fabric structure A.

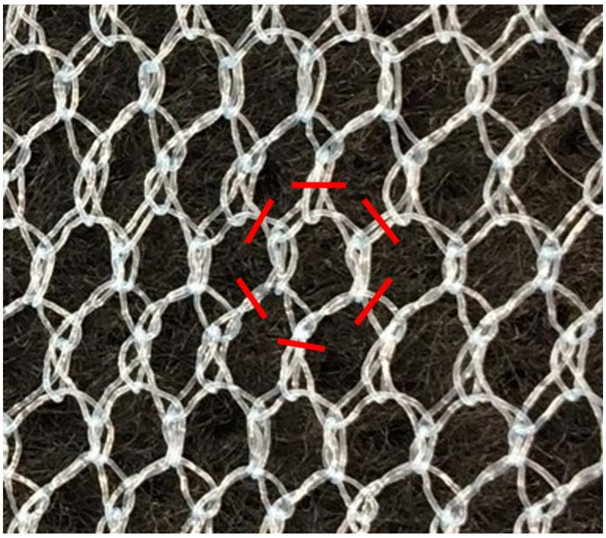

Figure 3 Example of wound position on warp knitted ITN fabric structure B.

Test procedure

1. Mark the centre of the specimen.
2. Cut the centre of the specimen as shown in Figures 2 and 3 to remove a mesh section, creating a hole.
3. Place the specimen on the bursting strength tester ensuring that the hole area is positioned immediately above the centre of the diaphragm.
4. Clamp the specimen.
5. Commence inflation and deflation of the diaphragm (see Table 1).
6. Measure the end hole size in mm after testing, according to the maximum Feret's diameter.
7. Record the presence of any secondary failure (laddering, tearing, or unravelling).

Recording results

Measuring the end hole size

The end hole size is measured according to the maximum Feret's diameter. Examples of how to measure are given in Figures 4a and 4b.

Optical microscopy and image analysis may be employed to aid measurement of the end hole size, as well as to identify secondary failure (if required).

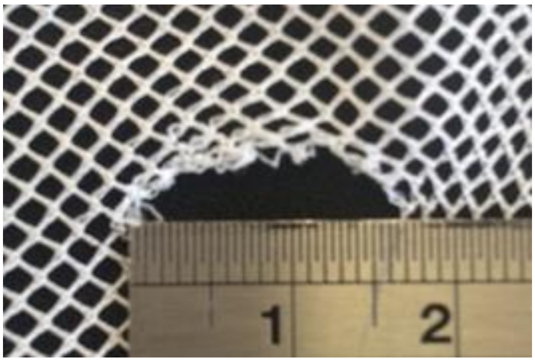

Figure 4a Example of measuring the wounded area after testing (the end hole size) in structure A. In this example the end hole measures 17 mm.

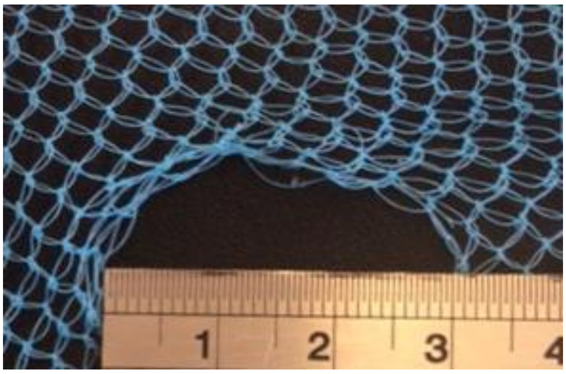

Figure 4b Example of measuring the wounded area after testing (the end hole size) in structure B. In this example the end hole measures 30 mm.

Assessment of secondary failure

In addition to the end hole size, record if the specimen shows any secondary failure. It should be noted that a hole in which secondary failure has occurred is likely to be elliptical or oblong in shape rather than circular.

There are three types of secondary failure as shown below:

- Laddering.
- Unravelling.

- Tearing, tearing combined with laddering or unravelling.

Identification of laddering

Laddering presents itself as sequential unlooped but unbroken yarns that run parallel in the knitted structure. The ladder itself does not form a hole.

In laddering two or more consecutive 'ladder rungs' must be visible in the structure. A ladder rung consists of unlooped yarns, but do not form a hole.

Figure 5 shows an example of laddering.

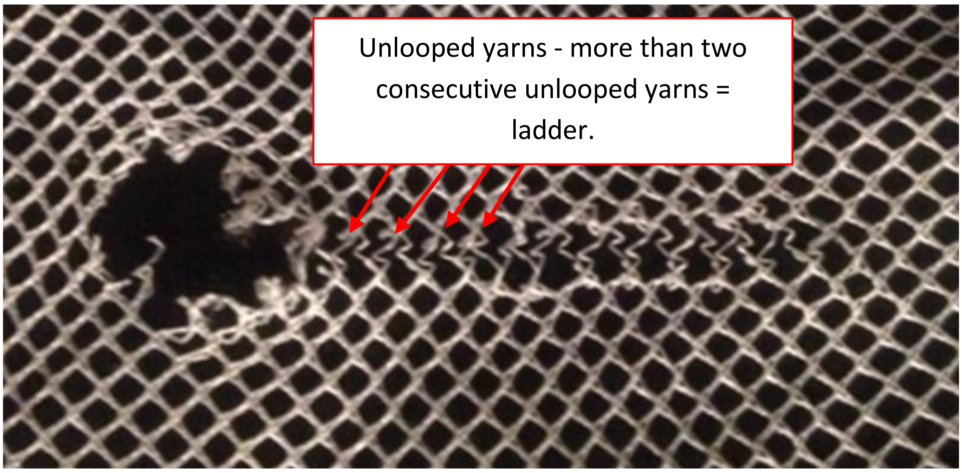

Figure 5 Structure A. Example of laderring. Multiple unlooped yarns are visible - two or more unlooped yarns associated with a ladder.

Identification of unravelling

In unravelling, the loops of the yarns sequentially disengage leading to a larger hole. This is characterised by open loops at the perimeter of the hole. Examples of unravelling are shown in Figures 6 and 7.

In unravelling, two or more consecutive unlooped yarns occur.

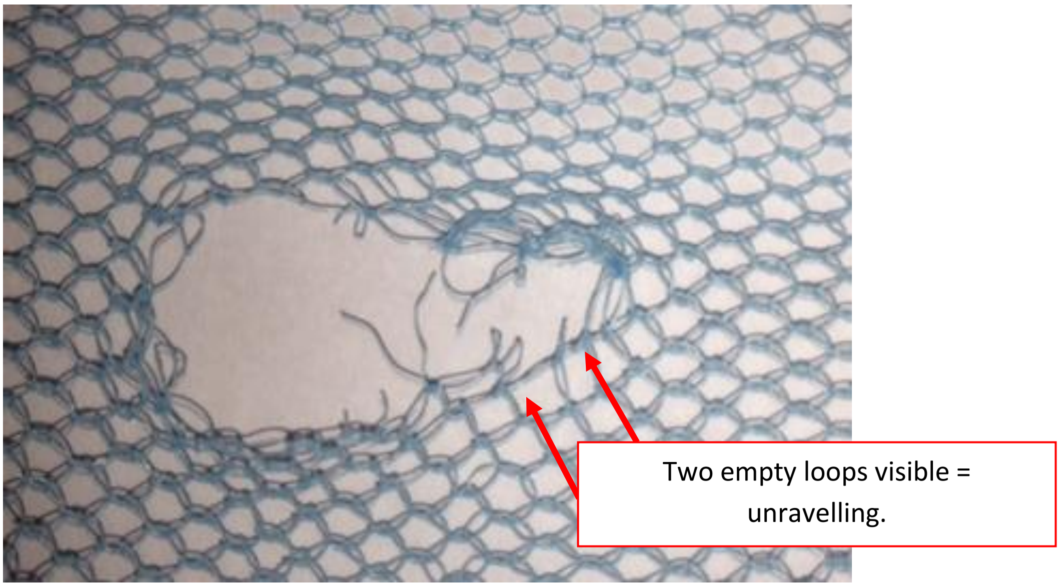

Figure 6 Structure B. Example of unravelling. Two empty loops are visible caused by unravelling.

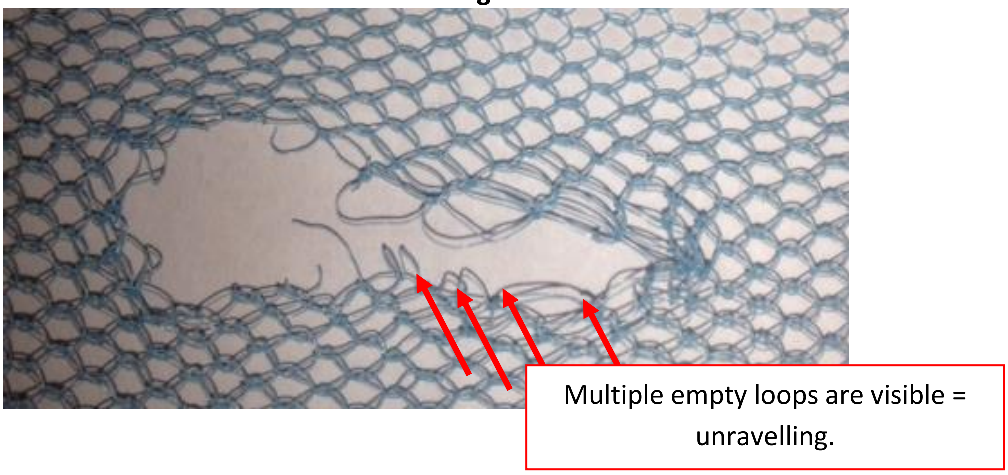

Figure 7 Structure B. Further example of unravelling. Multiple empty loops are visible.

Identification of tearing

Tearing is where one or more of the unlooped yarns associated with the ladder has broken as shown in Figure 8. The broken yarns create a hole. In tearing, two or more ‘ladder rungs’ are broken. Tearing is typically associated with a large end hole size of > 21mm.

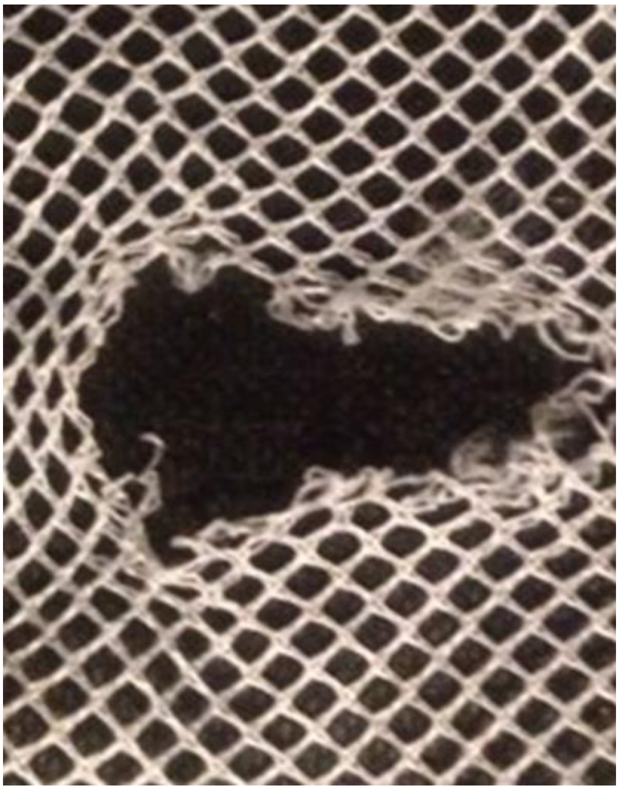

Figure 8 Structure A. Example of a tearing (broken rungs).

Hole Enlargement Resistance Scoring

The hole enlargement resistance score is based on:

(1) the average end hole size and,

(2) the presence (or not) of secondary damage in the form of laddering, unravelling, or tearing, as defined in Table 2.

The hole enlargement resistance score is determined by reference to Table 2.

First, identify which of the three end hole size categories in Table 2 correspond to the measured end hole size obtained in testing (<5 mm, 6-20 mm or >21 mm).

If there is no secondary damage, then report the hole enlargement resistance score shown on the line labelled 'none' (Table 2). If secondary damage is present, then report the hole enlargement resistance score corresponding to that type of damage shown in Table 2 (laddering, unravelling or tearing/tearing combined with laddering or unravelling).

If specimens of the same ITN sample exhibit different types of secondary damage, then report the hole enlargement resistance score that corresponds to the most serious type of damage observed in the specimens, (i.e. the damage type giving the lowest score).

Table 2 Hole enlargement resistance score.

	Average end hole size		
	< 5 mm	6 mm – 20 mm	> 21 mm
Damage Type			
None	100	80	n/a
Laddering	n/a	64	32
Unravelling	n/a	40	20
Tearing/tearing combined with laddering or unravelling	n/a	32	16

For example, referring to Table 2, if the average end hole size for a net is 15 mm and both laddering and unravelling are present, the hole enlargement resistance score will be 40 (as unravelling is associated with a lower hole enlargement resistance score than laddering; 40 < 64).

Determination of the hole enlargement resistance score is shown in Figure 9.

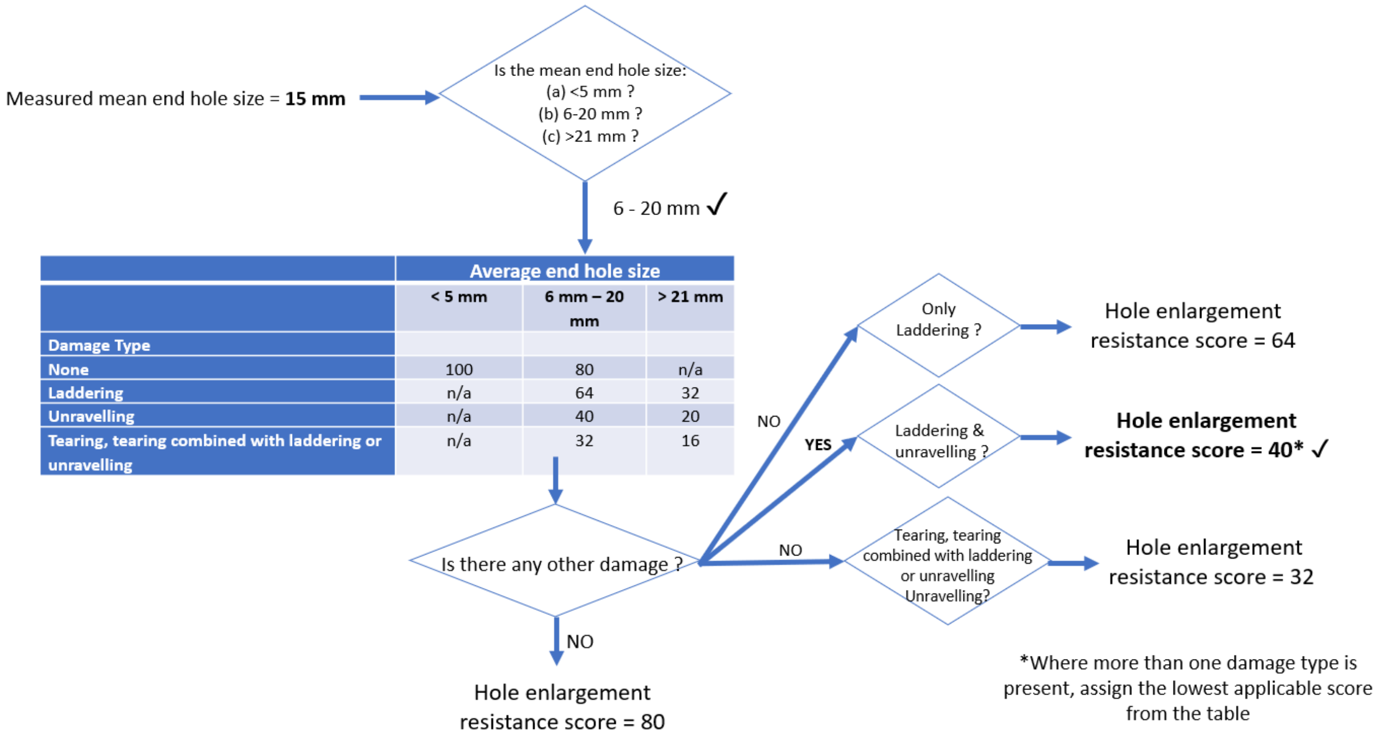

Figure 9 Flowchart for selecting the hole enlargement resistance score.

10. Assessment

Record:

- Average end hole size.
- Any observed secondary failure (laddering, unravelling or tearing).
- Hole enlargement resistance score.

Table 3 gives an example of how the raw data for a sample should be recorded.

Table 3 Example of test data.

Specimen Number	End hole size (mm)	Secondary failure				Hole enlargement resistance score
		None	**Laddering**	**Unravelling**	**Tearing**	
1	10	Y	N	N	N	
2	11	Y	N	N	N	
3	13	N	Y	N	Y	
4	10	Y	N	N	N	
5	12	N	Y	N	N	
6	10	N	N	N	N	
7	12	N	N	N	N	
8	13	N	N	N	N	
9	15	Y	Y	N	N	
10	14	N	Y	N	N	
11	13	Y	N	N	N	
12	10	Y	N	N	N	
13	11	N	Y	N	N	
14	16	Y	N	N	N	
15	20	N	Y	N	Y	
Average	**12.7**	**Tearing combined with laddering**				**32**

11. Test Report

The test report should include:

- Sample details and identity.
- The date the test is conducted.
- Testing machine manufacturer and model.
- The test operator.
- The location and laboratory.
- The conditions of testing if outside the testing conditions outlined in this document.
- The pressure (kPa) at which the test is undertaken.
- The end hole sizes after testing, and the average end hole size.
- The presence of any secondary damage.
- The hole enlargement resistance score.