THE
WOOLMARK
COMPANY

WOOL SCIENCE, TECHNOLOGY AND DESIGN EDUCATION PROGRAM

FACILITATOR GUIDE
THE DYEING OF WOOL

CONTENTS

4 **THE WOOLMARK COMPANY | AUSTRALIAN WOOL INNOVATION**

5 *The Wool Science, Technology and Design Education Program* overview

6 The Woolmark Learning Centre

7 **INTRODUCTION TO THIS FACILITATOR GUIDE**

8 **INTRODUCTION TO THIS COURSE**

8 Target audience

8 Course prerequisites

8 Course learning objectives

9 Course agenda

10 Module overview and learning objectives

12 Course materials and resources

13 The dyeing of wool demonstration kit

14 **ADMINISTRATIVE DETAILS**

14 Organisational responsibilities

14 Participant recognition

14 Program evaluation

15 Facilitator checklist

17 Room layout

18 A guideline for effective and engaging delivery

19 Appendix A: Learning styles questionnaire

33 **COURSE INTRODUCTION**

41 **COURSE AIMS**

42 **COURSE STRUCTURE**

43 **MODULE 1: THE PROCESS OF DYEING**

73 **MODULE 2: THE DYEING PROCESSES IN WOOL**

97 **MODULE 3: PREPARING WOOL FOR DYEING**

123 **MODULE 4: SELECTING AND APPLYING WOOL DYES**

149 **MODULE 5: DYEING AT VARIOUS STAGES IN WOOL PROCESSING**

217 **MODULE 6: SIDE EFFECTS OF DYEING**

243 **MODULE 7: DYEING OF WOOL BLENDS**

269 **MODULE 8: THE DYEHOUSE LABORATORY**

283 **MODULE 9: ENVIRONMENTAL IMPACTS ASSOCIATED WITH DYEING WOOL**

THE WOOLMARK COMPANY | AUSTRALIAN WOOL INNOVATION

The Woolmark Company (TWC) is a subsidiary of Australian Wool Innovation (AWI) and is the global authority on Merino wool. With a network that spans the entire global wool supply chain, The Woolmark Company builds awareness and promotes the unique traits of nature's finest fibre.

Australian Wool Innovation (AWI) is the research, development and marketing body for the Australian wool industry. More than 60,000 Australian woolgrowers co-invest with the Australian government to support the activities carried out by AWI and TWC along the global wool supply chain.

The Woolmark Company supports and connects global supply chain participants through initiatives such as The Wool Lab and Wool Lab Sport. These internationally renowned wool-sourcing tools provide designers, retailers and brands with the latest trends in wool yarns, fabrics and technologies, while promoting Australian Merino wool as the ultimate fibre of choice for apparel.

Marketing activities focus on education and awareness raising to ensure consumers, manufacturers and designers are aware of Australian wool's benefits and qualities, can capitalise on wool's inherent properties, and can successfully integrate wool into their product lines.

THE WOOL SCIENCE, TECHNOLOGY AND DESIGN EDUCATION PROGRAM OVERVIEW

The Wool Science, Technology and Design Education Program combines a series of introductory and advanced courses of study developed to meet the needs of tertiary-level participants studying within the fields of: textile science and engineering, fashion and textile design and/or textile manufacturing. Individual courses within the series may also be of interest to participants studying sheep and wool science, and those working in the wool production, raw wool processing, textile manufacturing and textile sales and marketing industries.

Introductory level courses are suitable for participants studying at first or second-year tertiary levels, while the advanced courses are aimed at participants in their more senior years of study. The extension courses can be used for specific course requirements.

INTRODUCTORY COURSES

- Wool fibre science
- Introduction to wool processing

ADVANCED COURSES

- Raw wool scouring
- Worsted top-making
- Worsted and woollen spinning
- **The dyeing of wool**
- Wool fabric finishing

EXTENSION COURSES (IN DEVELOPMENT)

- Finishing of wool knitwear
- Wastewater management
- Wool product quality
- Methods of wool fabric formation

THE WOOLMARK LEARNING CENTRE

The *Woolmark Learning Centre* is a freely accessible, online learning platform, which supports The Woolmark Company's commitment to education and awareness raising with regard to wool, wool processing and product innovation.

Make sure you have completed the *Wool Appreciation Course* online before delivering any courses of the *Wool Science, Technology and Design Education Program* to familiarise yourself with The Woolmark Company's approach and core messages about wool production and the wool supply chain.

It is also important to encourage all participants to explore the online *Woolmark Learning Centre* to reinforce and build on the knowledge they have gained by attending this advanced level course.

The W*oolmark Learning Centre* can be accessed at:
https://www.woolmarklearningcentre.com/

INTRODUCTION TO THIS FACILITATOR GUIDE

This Facilitator Guide covers *The dyeing of wool* course of the *Wool Science, Technology and Design Education Program*.

The information in this Guide will support you to:

- deliver the technical content across a series of face-to-face lectures in an engaging and easy-to-follow way
- carry out a range of practical demonstrations and interactive discussions to support participant learning.

This Facilitator Guide provides:

- an overview of the *Wool Science, Technology and Design Education Program* courses
- the target audience for *The dyeing of wool* course
- the pre-requisites for the course
- an overview and learning objectives for *The dyeing of wool*
- a suggested agenda for delivering *The dyeing of wool*
- an overview and the learning objectives for each module within *The dyeing of wool*
- course materials and resources required to deliver *The dyeing of wool*
- administrative requirements and institutional responsibilities when delivering *The dyeing of wool*
- guidelines and processes regarding participant recognition upon completing *The dyeing of wool*
- links to participant and facilitator feedback and evaluation questionnaires
- a facilitator checklist to enable successful planning and preparation leading up to, during and following delivery
- recommended room layout for small venues or groups
- a guideline for the effective and engaging delivery of the course content.

INTRODUCTION TO THIS COURSE

The dyeing of wool is an advanced-level course, which provides participants with an understanding of:

- knowledge on how and when wool is dyed
- information on how the fibre is prepared for dyeing and evaluated after dyeing
- the chemistry of wool dyeing
- the preparation of the fibre necessary for successful dyeing
- the dyes and recipes used for pure wool and blends
- how and when wool is dyed
- how dyeing operations are evaluated
- the side effects of dyeing and associated environmental issues.

The course structure and module plan contained in this Facilitator Guide indicate the technical content to be addressed, however it's important to adapt the focus of your training in line with participants' existing understanding and specific target audience requirements.

TARGET AUDIENCE

The dyeing of wool course is primarily aimed at senior-level tertiary participants studying textile science and engineering, and staff and managers from wool processing companies.

The course is designed to be delivered face to face, in groups of 6 – 50 people, although the ideal number of participants who can attend course lectures depends on the resources available to support the delivery.

COURSE PREREQUISITES

As an advanced course, *The dyeing of wool* is suitable for participants with sound knowledge of wool or the wool industry, or participants who have undertaken the introductory courses of the *Wool Science, Technology and Design Education Program* (e.g. Wool fibre science and Introduction to wool processing).

If this is the first *Wool Science, Technology and Design Education Program* course being delivered to these participants, start the initial lecture with an Introduction to *The Woolmark Company*.

This presentation is included in *The dyeing of wool* facilitator slides as an optional introductory module.

COURSE LEARNING OBJECTIVES

By the end of *The dyeing of wool* course, participants are expected to be able to:

- describe how to dye wool and blends, including the necessary preparation of the fibre and the machinery used
- evaluate the appropriateness of specific dyeing operations
- describe the side effects of dyeing and the associated environmental issues.

They will also have an understanding of wool dyeing, knowledge on how and when wool is dyed and information on how the fibre is prepared for dyeing and evaluated after dyeing.

COURSE AGENDA

The dyeing of wool course consists of 10 lectures, of approximately one hour each, supported by a set of PowerPoint slides, videos and recommended demonstrations, as outlined in the table below. **Note:** it is recommended to break Module 5 into two one-hour lectures, as indicated in the table below.

NOTE: Indicated slide numbers for Module 1 take account of the introductory Woolmark Company slides as outlined in the following facilitator notes.

MODULE | SLIDE NUMBER	VIDEOS AND PRACTICAL DEMONSTRATIONS
Module 1: The process of dyeing | 36 slides	Slide 10: The process of dyeing (demonstration part one) Slide 34: The process of dyeing (demonstration part two)
Module 2: The dyeing processes in wool | 22 slides	Slide 2: 3-D model of a wool fibre (handout)
Module 3: Preparing wool for dyeing | 23 slides	Slide 9: Bleached and unbleached sample comparison (handout) Slide 18: Bleached and unbleached heavily pigmented wool sample comparison (handout)
Module 4: Selecting and applying wool dyes | 23 slides	No videos or recommended demonstrations
Module 5: Dyeing at various stages in wool processing | 66 slides	Slide 7: Loose dyeing (video) Slide 9: Drying dyed loose stock (video) Slide 13: Fibre dyeing – top (video) Slide 15: Backwashing (video) Slide 16: Vigoureux printing (video) Slide 28: Hank dyeing and drying (video) Slide 44: Overflow jet drying process (video) Slide 60: Garment dyeing (video) Slide 63: Garment drying (video) **NOTE:** Break at Slide 35 Package drying
Module 6: Side effects of dyeing | 24 slides	No videos or recommended demonstrations
Module 7: Dyeing of wool blends | 23 slides	Slide 2: Wool-polyester blends (handout) Slide 13: Wool-cotton denim and cotton denim comparison (handout)
Module 8: The dyehouse laboratory | 11 slides	Slide 4: Colour measurement samples (handout) Slide 7: Wash fastness test samples (handout) Slide 8: Light fastness test samples (handout) Slide 9: Grey scales (handout)
Module 9: Environmental impacts associated with dyeing wool | 16 slides	Slide 4: Dyeing effluents (demonstration)

MODULE OVERVIEW AND LEARNING OBJECTIVES

Module 1 — The process of dyeing starts off this 9-module course by providing a review of the processes involved in dyeing of textile fibres.

By the end of this module participants are expected to be able to:

- outline the aims of the textile dyeing process
- explain how textiles are dyed
- outline the physical chemistry of dyeing
- differentiate between natural and synthetic fibres
- explain the use of natural and synthetic dyes
- describe the interaction between dyes and fibre types
- explain fibre chemistry in relation to dye sites,
- describe the concepts of circulation and affinity
- understand the importance of levelness and migration
- describe substantivity and fixation of dyes
- describe the processes employed to improve dye fastness.

Module 2 — By the end of The dyeing processes in wool module participants are expected to be able to review the structure of the wool fibre and the chemistry of keratin as they affect the dyeing of the fibre and explain the relationship between the stages in wool dyeing and its structure and chemistry.

Module 3 — Preparing wool for dyeing explains the methods used to prepare wool for dyeing, the particular issues that apply to bright colours (particularly bright blues) and the bleaching of wool (reason for bleaching and the methods used).

At the end of this module participants are expected to be able to:

- describe the techniques used to prepare wool in its various forms for dyeing
- the techniques used to ensure water used in dyeing is of suitable quality
- the preparation of chemically-treated wool
- bleaching processes used to prepare wool for dyeing to pastel shades
- conditions for balancing colour and fibre damage when bleaching
- the bleaching of pigmented wool.

Module 4 — Selecting and applying wool dyes explores the selection and implication of a suitable dye type for a given purpose, the use of dye auxiliaries, and the methods and recipes used to apply dyes at various stages of the wool processing pipeline.

At the end of this module participants are expected to be able to:

- list the criteria used to select wool dyes for a particular application
- explain the implications of the choice of dye for subsequent product performance
- describe the auxiliary products used in wool dyeing (the reasons and dangers)
- describe the recipes used to apply individual dye types
- explain the rationale for the recipes used
- appreciate the issues associated with trichromatic dyeing.

Module 5 — Dyeing at various stages in wool processing covers the preparation, processes and machinery involved with dyeing wool at various stages throughout the wool processing chain (loose stock, top, yarn, fabric and garment).

It also explores the advantages and disadvantages of each process including, the challenges and issues facing dyers and the quality control measures put in place to ensure an optimal dyeing outcome.

At the end of this module, participants are expected to be able to describe the preparation, processes and machinery used to dye wool at each stage of the wool processing stage, describe the advantages and disadvantages associated with dyeing at each stage of the wool processing stage and outline the key challenges faced when dyeing wool and the quality control measures employed.

Module 6 — Side effects of dyeing explores the many other changes in the fibre or fabric as a result of the dyeing operation in addition to imparting colour to the substrate.

It covers:

- damage to the fibre
- tippiness and skittery effects
- bulk in yarn
- excessive hygral expansion in fabrics
- running marks in piece dyeing
- inadequate dye fastness
- the methods of avoiding undesirable side effects
- the compromises required between damage, levelness and fastness.

At the end of this module, participants should be able to describe the types of damage that occur during wool dyeing, describe the impact of this damage on wool processing and the methods used to inhibit damage to wool during dyeing.

Module 7— Dyeing of wool blends reviews the reasons for blending wool with other fibres and the differences between the chemistry of commonly-blended fibres (both synthetic and natural). The module will then describe the impact of the different fibre chemistry on the blend dyeing process.

At the end of this module, participants should be able to outline the key differences in chemistry of the fibres commonly blended with wool, outline the impact of these differences in chemistry to the blend dyeing process and describe the different approaches taken to dye common wool blends.

Module 8 — The dyehouse laboratory explores this essential component of an efficient dyehouse and explains how the laboratory is the focus of all the control and development activities of the dyehouse.

By the end of this module participants will be able to describe the use and action of key test equipment used in a dyehouse laboratory.

Module 9 — The Environmental impacts associated with dyeing wool module covers some of the environmental issues associated with the wool dyeing process, including the dyeing of blends, which includes its own challenges.

The specific issues for wool that will be covered in this module include:

- the use of water and energy (an issue for all textiles)
- the use of chrome mordant dyes in wool dyeing
- the impact of statutory regulations on the release of chromium in mill effluent
- the problems associated with potassium dichromate
- the issues of 'superblacks'
- effluent from the dyeing of felt-resist treated top.

At the end of this module, participants should be able to nominate the environmental issues associated with dyeing of wool containing products and describe potential solutions for these problems.

COURSE MATERIALS AND RESOURCES

To deliver *The dyeing of wool* series of lectures, you will need the following materials:

Provided in each course Facilitator Pack

- Facilitator Guide (PDF provided via DropBox link)
- Facilitator slides (PowerPoint files for each module provided via DropBox link)
- participant sign-on sheet (Word template provided via DropBox link)
- Participant Guide (PDF provided via DropBox link)
- Demonstration kit (see details below)
- Certificates of Participation (supplied by the regional Woolmark Company office on confirmation of student numbers).

To be sourced by facilitators

- speakers (for listening to the videos)
- laptop, data projector and overhead screen
- participant name tags (e.g. sticky labels or equivalent and a black marker to write participant names)
- flipchart and paper or access to a whiteboard
- markers for the flipchart or whiteboard where available

NOTE: The WST&DEP materials are designed to be delivered on a Microsoft 365 platform, on a 64bit hard drive. Please contact the regional Woolmark office if you do not have access to adequate technology.

THE DYEING OF WOOL DEMONSTRATION KIT

A range of practical demonstrations, group activities, handouts and samples is recommended to be used throughout this course to support participant learning and complement the content delivered in the lectures.

Recommended resources are listed at the start of each module in *The dyeing of wool* Facilitator Guide.

The following samples and resources for demonstrations are provided in *The dyeing of wool* Demonstration kit (resources not supplied in the kit will need to be supplied by the facilitator):

Module 1:
- sample of wool fabric
- sample of cotton fabric

Module 2:
- 3-D wool fibre model

Module 3:
- samples of wool in natural and bleached state
- samples of pigmented wool in natural and bleached state

Module 5:
- dyed and undyed loose wool
- dyed and undyed top
- dyed and undyed yarn in hank
- dyed and undyed yarn in package
- dyed and undyed knitted fabric
- dyed and undyed woven fabric
- dyed and undyed garment

Module 6:
- No resources required for this module

Module 7:
- wool polyester fabric – wool dyed only (fibre mixture)
- wool polyester fabric – wool dyed only (stripe)
- wool polyester – both dyed
- wool – cotton denim sample
- cotton denim sample

Module 8:
- grey scales – colour change
- grey scales – staining
- light fastness samples
- wash fastness samples

Module 9:
- carbon black
- solution of a vegetable dye

ADMINISTRATIVE DETAILS

ORGANISATIONAL RESPONSIBILITIES

Institutions delivering the *Wool Science, Technology and Design Education Program* course *The dyeing of wool* will be responsible for:

- ensuring all facilitators have completed the online *Wool Appreciation Course* prior to delivering their first course
- providing the venue and equipment required to support the program (i.e. lecture theatre, data projector, data screen, flip chart, whiteboard and markers)
- enrolling the participants in the course
- ensuring all participants have undertaken the prerequisite courses of study or have sufficient industry knowledge to complete this advanced course of study
- administrative paperwork (i.e. participant sign-in sheets, name tags etc.)
- providing administrative support for communication between the facilitator and the participants
- ensuring both the participants and the facilitator have the required access to external sites required to support participant learning
- providing supporting services, as required. (e.g. interpreter, transport to or from external sites)
- providing The Woolmark Company with participant numbers, and participant and facilitator feedback and course evaluation post delivery.

The Woolmark Company will be responsible for providing:

- Facilitator Guide (PDF provided via DropBox link)
- Facilitator slides (PowerPoint files for each module provided via DropBox link)
- Participant sign-on sheet (Word template provided via DropBox link)
- Participant Guide (PDF provided via DropBox link)
- Demonstration kit
- Certificates of Participation (printed copies will be provided by the local TWC office upon request).

NOTE: Course materials are provided in English. If translation to the local language is required, this is the responsibility of the delivering institution.

PARTICIPANT RECOGNITION

At the conclusion of the nine *The dyeing of wool* lectures, each participant who has attended all lectures is eligible to receive a Woolmark Company-endorsed Certificate of Participation.

Certificates of Participation will be supplied by the regional Woolmark Company office upon request.

Ensure you have contact details for each participant (or the relevant institution) and record attendance at each lecture (on an attendance sheet or other method of your choice).

At the completion of the course deliver a Certificate of Participation to each eligible participant.

PROGRAM EVALUATION

Feedback from those attending *The dyeing of wool* course must be collected by way of an online survey link. This feedback will be used to adapt the course on an annual basis, if and where necessary, to ensure it achieves the desired objectives in the most effective way.

Feedback from those delivering *The dyeing of wool* course also must be submitted at the completion of the course. This feedback can be submitted via the online survey.

Facilitator survey:
www.woolmarklearningcentre.com/wstd-surveyfacilitator

Participant survey:
www.woolmarklearningcentre.com/wstd-surveyparticipant

FACILITATOR CHECKLIST

The following list outlines the actions required before, during and after delivery of *The dyeing of wool* course.

One month before:

- ☐ Fully familiarise yourself with the course materials.
- ☐ Check you have all the materials required to deliver the course (including the facilitator materials and the demonstration kit).
- ☐ If you are an external facilitator, obtain contact details for your key point of contact at the host institution. Make contact, introduce yourself and arrange regular meetings leading up to the delivery dates.
- ☐ Confirm the number of participants attending, along with the year level and any previous studies relevant to the course.
- ☐ Confirm any specific needs for the target audience in consultation with the institution.
- ☐ Familiarise yourself with the venue and facilities that will be available for the lectures including room size and potential room layout options (see following notes regarding room layout). This may be via site maps or discussions with your key contact.
- ☐ Confirm equipment available at the venue (e.g. data projector, screen, speakers, laboratory equipment).
- ☐ Adapt the program (if required) to meet the needs of the participants and venue facilities.
- ☐ Check the availability of participant materials in sufficient quantity.
- ☐ Ensure you have reviewed the delivery material and have checked any videos for the upcoming lectures work on the available equipment.

One week before:

- ☐ Confirm shipping details of the course materials and equipment (if required)
- ☐ Confirm transport between the institution and any external site visits. (if required).
- ☐ Confirm names of the participants attending the course.
- ☐ Ensure you have ordered a sufficient number of the 'Certificate of Participation' to be distributed to the appropriate participants following the completion of the final lecture.
- ☐ Ensure your wardrobe contains various wool garments. In order to demonstrate the benefits and versatility of wool and wool products, facilitators are encouraged to wear as much wool as possible, across a range of garment types. For example:
    - wool trousers or skirt
    - wool t-shirt or undershirt, long-sleeved shirt, sweater or jacket
    - wool socks.

One day before:

- ☐ Arrange to meet your key institution contacts face to face and any key contacts at external sites (if required).
- ☐ Familiarise yourself with the venue's emergency procedures.
- ☐ Tour the facility. Visit the rooms you will be using.
- ☐ Check the equipment you need is available in working order and you know how to use it (including lighting, heating and cooling).
- ☐ Ensure you have reviewed the delivery material and have checked any videos for the upcoming lectures will work on the available equipment (e.g. speakers).
- ☐ Familiarise yourself with the rest rooms available at the venue.
- ☐ Take note of any challenges associated with each room (e.g. noise, heat, lighting). Identify strategies to minimise these challenges.
- ☐ Prepare the student materials you will need to distribute at the first lecture (e.g. participant name tags and sign-in sheets).
- ☐ Check you have all the materials you need to deliver the course (including the Participant Guides).
- ☐ Distribute the PDF (soft copy) of the Participant Guide to participants prior to the first lecture if possible, to allow them to become familiar with the course materials and content.

Prior to each lecture:

- ☐ Ensure you are wearing a variety of wool garments that reflect the benefits and versatility of wool and wool products.
- ☐ Arrive 30 minutes before each lecture to check the equipment is available and working.

At commencement of the first lecture:

- ☐ Distribute the hard copy of the Participant Guide to each participant.
- ☐ Distribute name tags to each participant.
- ☐ Record those who are present.

After each lecture:

- ☐ Stay to answer any questions the participants may have about the course content.

Prior to the final lecture:

- ☐ Ensure you have received a sufficient number of the 'Certificates of Participation' to be distributed to the appropriate students following the completion of the final lecture.

At the completion of the course:

- ☐ Provide participants with the online feedback and evaluation survey link.
- ☐ Complete and submit your own online evaluation survey.
- ☐ Provide feedback to the institution regarding the successful completion of the course.
- ☐ Explore future delivery opportunities and liaise with The Woolmark Company regional office.

Post-course survey links:

Facilitator survey:
www.woolmarklearningcentre.com/wstd-surveyfacilitator

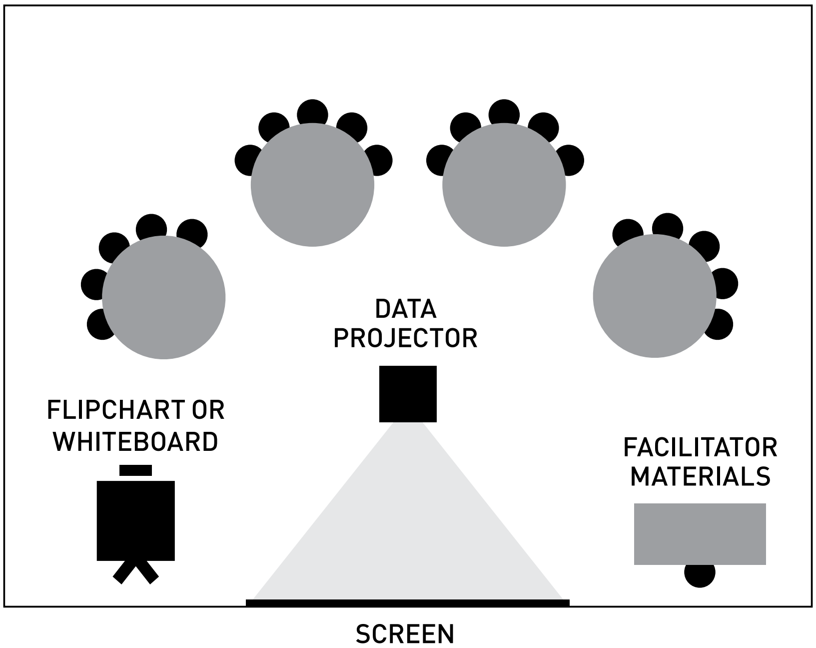
Participant survey:
www.woolmarklearningcentre.com/wstd-surveyparticipant

ROOM LAYOUT

The dyeing of wool course is designed to be delivered face-to-face, in groups of 6 – 50 people. In many cases this will mean delivery occurs in a large lecture theatre and there will not be an opportunity to influence the physical learning environment.

In smaller groups and settings where the learning environment can be influenced:

- arrange tables in a cabaret style (see diagram below) facing a flipchart or whiteboard and a data projector/screen
- allow for small group discussion in groups of three or four.



A GUIDELINE FOR THE EFFECTIVE AND ENGAGING DELIVERY OF THE COURSE CONTENT.

The course materials are designed to achieve a Gunning Fog Index of 8–10, with the exclusion of technical terms specific to the course.

The Gunning Fog Index formula implies short sentences written in plain English achieve a better score than long sentences written in complicated language.

Materials with a Gunning Fog Index of 8 have a readability equivalent to a Grade 8 reading level for English speaking students. It is considered the ideal score for readability. Anything above 12 is too hard for most people to read[1].

Information is provided in Appendix A for facilitators who wish to enhance their skills in facilitation by acknowledging the different learning styles of participants.

Research has shown each person has a preferred way of learning[2]. As adults, we tend to adopt the learning style with which we are most comfortable and ignore learning styles with which we are unfamiliar or uncomfortable. This means learning is most effective when a student can process information and solve problems in a way that is meets their preferred learning style.

When you know a person's learning style, you can present information to them so they can grasp it quickly and easily. If information is presented in a way that is at odds with their preferred learning style, the student will find it more difficult to learn. Sometimes this means, as a facilitator, you may have to present information to a student in a way that will engage them, although that may not be your preferred method. If you do not accommodate the student's preferred learning style, you make it harder to get the message across, which may lead to frustration on your part, as well as a lack of commitment from the student.

Honey & Mumford have developed a questionnaire, included in Appendix A, which helps you identify your students' preferred learning styles.

1 http://www.usingenglish.com/glossary/fog-index.html, http://juicystudio.com/services/readability.php
2 Kolb D. A. (1984). Experiential Learning experience as a source of learning and development, New Jersey: Prentice Hall.

APPENDIX A: LEARNING STYLES QUESTIONNAIRE

NAME: ______________________________

This questionnaire is designed to find out your preferred learning style(s). Over the years you have probably developed learning "habits" that help you benefit more from some experiences than from others. Since you are probably unaware of this, this questionnaire will help you pinpoint your learning preferences so that you are in a better position to select learning experiences that suit your style and having a greater understanding of those that suit the style of others.

This is an internationally proven tool designed by Peter Honey and Alan Mumford.

There is no time limit to this questionnaire. It will probably take you 10-15 minutes. The accuracy of the results depends on how honest you can be. There are no right or wrong answers.

If you agree more than you disagree with a statement put a tick by it.

If you disagree more than you agree put a cross by it.

Be sure to mark each item with either a tick or cross.

- □ 1. I have strong beliefs about what is right and wrong, good and bad
- □ 2. I often act without considering the possible consequences
- □ 3. I tend to solve problems using a step-by-step approach
- □ 4. I believe that formal procedures and policies restrict people
- □ 5. I have a reputation for saying what I think, simply and directly
- □ 6. I often find that actions based on feelings are as sound as those based on careful thought and analysis
- □ 7. I like the sort of work where I have time for thorough preparation and implementation
- □ 8. I regularly question people about their basic assumptions
- □ 9. What matters most is whether something works in practice
- □ 10. I actively seek out new experiences
- □ 11. When I hear about a new idea or approach I immediately start working out how to apply it in practice
- □ 12. I am keen on self discipline such as watching my diet, taking regular exercise, sticking to a fixed routine, etc
- □ 13. I take pride in doing a thorough job
- □ 14. I get on best with logical, analytical people and less well with spontaneous, 'irrational' people
- □ 15. I take care over the interpretation of data available to me and avoid jumping to conclusions
- □ 16. I like to reach a decision carefully after weighing up many alternatives
- □ 17. I'm attracted more to novel, unusual ideas than to practical ones
- □ 18. I don't like disorganised things and prefer to fit things into a coherent pattern
- □ 19. I accept and stick to laid down procedures and policies so long as I regard them as an efficient way of getting the job done
- □ 20. I like to relate my actions to a general principle
- □ 21. In discussions I like to get straight to the point
- □ 22. I tend to have distant, rather formal relationships with people at work
- □ 23. I thrive on the challenge of tackling something new and different
- □ 24. I enjoy fun-loving, spontaneous people
- □ 25. I pay meticulous attention to detail before coming to a conclusion
- □ 26. I find it difficult to produce ideas on impulse
- □ 27. I believe in coming to the point immediately
- □ 28. I am careful not to jump to conclusions too quickly
- □ 29. I prefer to have as many resources of information as possible – the more data to think over the better
- □ 30. Flippant people who don't take things seriously enough usually irritate me
- □ 31. I listen to other people's points of view before putting my own forward
- □ 32. I tend to be open about how I'm feeling
- □ 33. In discussions I enjoy watching the manoeuvrings of the other participants
- □ 34. I prefer to respond to events on a spontaneous, flexible basis rather than plan things out in advance

- ☐ 35. I tend to be attracted to techniques such as network analysis, flow charts, branching programs, contingency planning, etc
- ☐ 36. It worries me if I have to rush out a piece of work to meet a tight deadline
- ☐ 37. I tend to judge people's ideas on their practical merits
- ☐ 38. Quiet, thoughtful people tend to make me feel uneasy
- ☐ 39. I often get irritated by people who want to rush things
- ☐ 40. It is more important to enjoy the present moment than to think about the past or future
- ☐ 41. I think that decisions based on a thorough analysis of all the information are sounder than those based on intuition
- ☐ 42. I tend to be a perfectionist
- ☐ 43. In discussions I usually produce lots of spontaneous ideas
- ☐ 44. In meetings I put forward practical realistic ideas
- ☐ 45. More often than not, rules are there to be broken
- ☐ 46. I prefer to stand back from a situation
- ☐ 47. I can often see inconsistencies and weaknesses in other people's arguments
- ☐ 48. On balance I talk more than I listen
- ☐ 49. I can often see better, more practical ways to get things done
- ☐ 50. I think written reports should be short and to the point
- ☐ 51. I believe that rational, logical thinking should win the day
- ☐ 52. I tend to discuss specific things with people rather than engaging in social discussion
- ☐ 53. I like people who approach things realistically rather than theoretically
- ☐ 54. In discussions I get impatient with irrelevancies and digressions
- ☐ 55. If I have a report to write I tend to produce lots of drafts before settling on the final version
- ☐ 56. I am keen to try things out to see if they work in practice
- ☐ 57. I am keen to reach answers via a logical approach
- ☐ 58. I enjoy being the one that talks a lot
- ☐ 59. In discussions I often find I am the realist, keeping people to the point and avoiding wild speculations
- ☐ 60. I like to ponder many alternatives before making up my mind
- ☐ 61. In discussions with people I often find I am the most dispassionate and objective
- ☐ 62. In discussions I'm more likely to adopt a "low profile" than to take the lead and do most of the talking
- ☐ 63. I like to be able to relate current actions to a longer term bigger picture
- ☐ 64. When things go wrong I am happy to shrug it off and "put it down to experience"
- ☐ 65. I tend to reject wild, spontaneous ideas as being impractical
- ☐ 66. It's best to think carefully before taking action
- ☐ 67. On balance I do the listening rather than the talking
- ☐ 68. I tend to be tough on people who find it difficult to adopt a logical approach
- ☐ 69. Most times I believe the end justifies the means
- ☐ 70. I don't mind hurting people's feelings so long as the job gets done
- ☐ 71. I find the formality of having specific objectives and plans stifling
- ☐ 72. I'm usually one of the people who puts life into a party
- ☐ 73. I do whatever is expedient to get the job done
- ☐ 74. I quickly get bored with methodical, detailed work
- ☐ 75. I am keen on exploring the basic assumptions, principles and theories underpinning things and events
- ☐ 76. I'm always interested to find out what people think
- ☐ 77. I like meetings to be run on methodical lines, sticking to laid down agenda, etc.
- ☐ 78. I steer clear of subjective or ambiguous topics
- ☐ 79. I enjoy the drama and excitement of a crisis situation
- ☐ 80. People often find me insensitive to their feelings

SCORING AND INTERPRETING THE LEARNING STYLES QUESTIONNAIRE

The Questionnaire is scored by awarding one point for each ticked item. There are no points for crossed items. Simply indicate on the lists below which items were ticked by circling the appropriate question number.

	2	7	1	5
	4	13	3	9
	6	15	8	11
	10	16	12	19
	17	25	14	21
	23	28	18	27
	24	29	20	35
	32	31	22	37
	34	33	26	44
	38	36	30	49
	40	39	42	50
	43	41	47	53
	45	46	51	54
	48	52	57	56
	58	55	61	59
	64	60	63	65
	71	62	68	69
	72	66	75	70
	74	67	77	73
	79	76	78	80
TOTALS	________	________	________	________
	Activist	**Reflector**	**Theorist**	**Pragmatist**

LEARNING STYLES QUESTIONNAIRE PROFILE BASED ON GENERAL NORMS FOR 1302 PEOPLE

ACTIVIST	REFLECTOR	THEORIST	PRAGMATIST	
20	20	20	20	Very strong preference
19				
18		19	19	
17				
16		18		
15		17	18	
14				
13	18	16	17	
12	17	15	16	Strong preference
	16			
11	15	14	15	
10	14	13	14	Moderate
9	13	12	13	
8				
7	12	11	12	
6	11	10	11	Low preference
5	10	9	10	
4	9	8	9	
3	8	7	8	Very low preference
	7	6	7	
	6	5	6	
2	5	4	4	
	4	3	3	
	3			
1	2	2	2	
	1	1	1	
0	0	0	0	

LEARNING STYLES – GENERAL DESCRIPTIONS

Activists

Activists involve themselves fully and without bias in new experiences. They enjoy the here and now and are happy to be dominated by immediate experiences. They are open-minded, not sceptical, and this tends to make them enthusiastic about anything new. Their philosophy is: "I'll try anything once". They tend to act first and consider the consequences afterwards. Their days are filled with activity. They tackle problems by brainstorming. As soon as the excitement from one activity has died down they are busy looking for the next. They tend to thrive on the challenge of new experiences but are bored with implementation and longer-term consolidation. They are gregarious people constantly involving themselves with others but in doing so they seek to centre all activities on themselves.

Reflectors

Reflectors like to stand back to ponder experiences and observe them from many different perspectives. They collect data, both first hand and from others, and prefer to think about it thoroughly before coming to any conclusion. The thorough collection and analysis of data about experiences and events is what counts so they tend to postpone reaching definitive conclusions for as long as possible. Their philosophy is to be cautious. They are thoughtful people who like to consider all possible angles and implications before making a move. They prefer to take a back seat in meetings and discussions. They enjoy observing other people in action. They listen to others and get the drift of the discussion before making their own points. They tend to adopt a low profile and have a slightly distant, tolerant unruffled air about them. When they act it is part of a wide picture which includes the past as well as the present and others' observations as well as their own.

Theorists

Theorists adapt and integrate observations into complex but logically sound theories. They think problems through in a vertical, step-by-step logical way. They assimilate disparate facts into coherent theories. They tend to be perfectionists who won't rest easy until things are tidy and fit into a rational scheme. They like to analyse and synthesise. They are keen on basic assumptions, principles, theories models and systems thinking. Their philosophy prizes rationality and logic. "If it's logical it's good". Questions they frequently ask are: "Does it make sense?" "How does this fit with that?" "What are the basic assumptions?" They tend to be detached, analytical and dedicated to rational objectivity rather than anything subjective or ambiguous. Their approach to problems is consistently logical. This is their "mental set" and they rigidly reject anything that doesn't fit with it. They prefer to maximise certainty and feel uncomfortable with subjective judgments, lateral thinking and anything flippant.

Pragmatists

Pragmatists are keen on trying out ideas, theories and techniques to see if they work in practice. They positively search out new ideas and take the first opportunity to experiment with applications. They are the sorts of people who return from management courses brimming with new ideas that they want to try out in practice. They like to get on with things and act quickly and confidently on ideas that attract them. They tend to be impatient with ruminating and open-ended discussions. They are essentially practical, down to earth people who like making practical decisions and solving problems. They respond to problems and opportunities "as a challenge". Their philosophy is: "There is always a better way" and "if it works it's good".

In descending order of likelihood, the most common combinations are:

1st Reflector/Theorist
2nd Theorist/Pragmatist
3rd Reflector/Pragmatist
4th Activist/Pragmatist

LEARNING STYLES – A FURTHER PERSPECTIVE

ACTIVISTS:

Activists *learn best from activities where:*

- There are new experiences/problems/opportunities from which to learn.
- They can engross themselves in short "here and now" activities such as business games, competitive teamwork tasks, role-playing exercises.
- There is excitement/drama/crisis and things chop and change with a range of diverse activities to tackle
- They have a lot of the limelight/high visibility, i.e. they can "chair" meetings, lead discussions, and give presentations.
- They are allowed to generate ideas without constraints of policy or structure or feasibility.
- They are thrown in at the deep end with a task they think is difficult, i.e. when set a challenge with inadequate resources and adverse conditions.
- They are involved with other people, i.e. bouncing ideas off them, solving problems as part of a team.
- It is appropriate to "have a go".

Activists *learn least from, and may react against, activities where:*

- Learning involves a passive role, i.e. listening to lectures, monologues, explanations, statements of how things should be done, reading, watching.
- They are asked to stand back and not be involved.
- They are required to assimilate, analyse and interpret lots of "messy" data.
- They are required to engage in solitary work, i.e. reading, writing, thinking on their own.
- They are asked to assess beforehand what they will learn, and to appraise afterwards what they have learned.
- They are offered statements they see as "theoretical", i.e. explanation of cause or background
- They are asked to repeat essentially the same activity over and over again, i.e. when practicing.
- They have precise instructions to follow with little room for manoeuvre.
- They are asked to do a thorough job, i.e. attend to detail, tie up loose ends, dot the i's, cross t's.

Summary of strengths

- Flexible and open minded.
- Happy to have a go.
- Happy to be exposed to new situations.
- Optimistic about anything new and therefore unlikely to resist change.

Summary of weaknesses:

- Tendency to take the immediately obvious action without thinking.
- Often take unnecessary risks.
- Tendency to do too much themselves and hog the limelight.
- Rush into action without sufficient preparation.
- Get bored with implementation/consolidation.
- Key questions for activists:
- Shall I learn something new, i.e. that I didn't know/ couldn't do before?
- Will there be a wide variety of different activities? (I don't want to sit and listen for more than an hour at a stretch!)
- Will it be OK to have a go/let my hair down/make mistakes/have fun?
- Shall I encounter some tough problems and challenges?
- Will there be other like-minded people to mix with?

REFLECTORS:

Reflectors *learn best from activities where:*

- They are allowed or encouraged to watch/think/chew over activities.
- They are able to stand back from events and listen/ observe, i.e. observing a group at work, taking a back seat in a meeting, watching a film or video.
- They are allowed to think before acting, to assimilate before commencing, i.e. time to prepare, a chance to read in advance a brief giving background data.
- They can carry out some painstaking research, i.e. investigate, assemble information, and probe to get to the bottom of things.
- They have the opportunity to review what has happened, what they have learned.
- They are asked to produce carefully considered analyses and reports.

- They are helped to exchange views with other people without danger, i.e. by prior agreement, within a structured learning experience.
- They can reach a decision in their own time without pressure and tight deadlines.

Reflectors *learn least from, and may react against, activities where:*

- They are "forced" into the limelight, i.e. to act as leader/chairman, to role-play in front of on-lookers.
- They are involved in situations which require action without planning.
- They are pitched into doing something without warning, i.e. to produce an instant reaction, to produce an off-the-top-of-the-head idea.
- They are given insufficient data on which to base a conclusion.
- They are given cut and dried instructions of how things should be done.
- They are worried by time pressures or rushed from one activity to another.
- In the interests of expediency they have to make short cuts or do a superficial job.

Summary of strengths:

- Careful.
- Thorough and methodical
- Thoughtful
- Good at listening to others and assimilating information.
- Rarely jump to conclusions.

Summary of weaknesses:

- Tendency to hold back from direct participation.
- Slow to make up their minds and reach a decision.
- Tendency to be too cautious and not take enough risks.
- Not assertive - they aren't particularly forthcoming and have no "small talk".

Key questions for reflectors:

- Shall I be given adequate time to consider, assimilate and prepare?
- Will there be opportunities/facilities to assemble relevant information?
- Will there be opportunities to listen to other people's points of view – preferably a wide cross section of people with a variety of views?
- Shall I be under pressure to be slapdash or to extemporise?

THEORISTS:

Theorists *learn best from activities where:*

- What is being offered is part of a system, model, concept, or theory.
- The have time to explore methodically the associations and inter-relationships between ideas, events and situations.
- They have the chance to question and probe the basic methodology, assumptions or logic behind something, i.e. by taking part in a question and answer session, by checking a paper for inconsistencies.
- They are intellectually stretched, i.e. by analysing a complex situation, being tested in a tutorial session, by teaching high calibre people who ask searching questions.
- They are in structured situations with a clear purpose.
- They can listen to or read about ideas and concepts that emphasise rationality or logic and are well argued/elegant/watertight.
- They can analyse and then generalise the reasons for success or failure.
- They are offered interesting ideas and concepts even though they are not immediately relevant.
- They are required to understand and participate in complex situations.

Theorists *learn least from, and may react against, activities where:*

- They are pitch-forked into doing something without a context or apparent purpose.
- They have to participate in situations emphasising emotions and feelings.
- They are involved in unstructured activities where ambiguity and uncertainty are high, i.e. with open¬ended problems, on sensitivity training.
- They are asked to act or decide without a basis in policy, principle or concept.
- They are faced with a hotchpotch of alternative/contradictory techniques/methods without exploring any in depth, i.e. as on a "once over lightly" course.
- They find the subject matter platitudinous, shallow or gimmicky.
- They feel themselves out of tune with other participants, i.e. when with lots of Activists or people of lower intellectual calibre.

Summary of strengths:

- Logical "vertical" thinkers.
- Rational and objective.
- Good at asking probing questions.
- Disciplined approach.

Summary of weaknesses:

- Restricted in lateral thinking.
- low tolerance for uncertainty, disorder and ambiguity
- Intolerant of anything subjective or intuitive.
- Full of "shoulds, oughts and musts".

Key questions for theorists:

- Will there be lots of opportunities to question?
- Do the objectives and program of events indicate a clear structure and purpose?
- Shall I encounter complex ideas and concepts that are likely to stretch me?
- Are the approaches to be used and concepts to be explored "respectable", i.e. sound and valid?
- Shall I be with people of similar calibre to myself?

PRAGMATIST:

Pragmatists *learn best from activities where:*

- There is an obvious link between the subject matter and a problem or opportunity on the job.
- They are shown techniques for doing things with obvious practical advantages, i.e. how to save time, how to make a good first impression, how to deal with awkward people.
- They have the chance to try out and practice techniques with coaching/feedback from a credible expert, i.e. someone who is successful and can do the techniques themselves.
- They are exposed to a model they can emulate, i.e. a respected boss, a demonstration from someone with a proven track record, lots of examples/anecdotes, and a film showing how it's done.
- They are given techniques currently applicable to their own job.
- They are given immediate opportunities to implement what they have learned.
- There is a high face validity in the learning activity, i.e. a good simulation, "real" problems.
- They can concentrate on practical issues, i.e. drawing up action plans with an obvious end product, suggesting short cuts, giving tips.

Pragmatists *learn least from, and may react against, activities where:*

- The learning is not related to an immediate need they recognise/they cannot see, an immediate relevance/practical benefit.
- Organisers of the learning, or the event itself, seems distant from reality, i.e. "ivory towered", all theory and general principles, pure "chalk and talk".
- There is no practice or clear guidelines on how to do it.
- They feel that people are going round in circles and not getting anywhere fast enough.
- There are political, managerial or personal obstacles to implementation.
- There is no apparent reward from the learning activity, i.e. more sales, shorter meetings, higher bonus, promotion.

Summary of strengths:

- Keen to test things out in practice.
- Practical, down to earth, realistic.
- Businesslike – gets straight to the point.
- Technique oriented.

Summary of weaknesses:

- Tendency to reject anything without an obvious application.
- Not very interested in theory or basic principles.
- Tendency to seize on the first expedient solution to a problem.
- Impatient with waffle.
- On balance, task oriented not people oriented.

Key questions for pragmatists:

- Will there be ample opportunities to practice and experiment?
- Will there be lots of practical tips and techniques?
- Shall we be addressing real problems and will it result in action plans to tackle some of my current problems?
- Shall we be exposed to experts who know how to/can do it themselves?

GLOSSARY

ACRONYMS, ABBREVIATIONS AND UNITS OF MEASUREMENT

AOX	Adsorbable organic halide, a type of pollutant that is an organic molecule containing one or more fluorine, chlorine, bromine or iodine atoms.
AWI	Australian Wool Innovation
CMC	Cell membrane complex
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCCA	Dichloro-isocyanuric acid
DCM	Dichloromethane
EDTA	Ethylenediaminetetraacetic acid
EU	European Union
ISO	International Standards Organisation
REACH	Registration, Evaluation, Authorisation and restriction of Chemicals, EU chemicals policy
RF	Radio frequency, used for thermal drying of wet wool
WIRA	Wool Industries Research Association

Term	Definition
adsorption	The movement of the dye molecules from the aqueous solution to the surface of the fibre; sometimes also used in the context of adsorption of dye molecules to a dye site within the fibre.
affinity	A quantitative measure of the attraction between the fibre and the dye.
aniline black dyes	Dyes based on an aniline structure which can be oxidised to form an intense black chromophore.
anionic dyes	Dyes in which the dye molecule is negatively charged.
approach	The movement of the dye liquor through the fibre mass yarn, fabric allowing movement of the dye molecules to the fibre. Controlled by liquor circulation.
auxiliaries	Chemicals used to facilitate dyeing such as: • levelling agents • antifoams • blocking agents • pH adjust • protecting agents.
auxochrome	The component of the dye that modifies the colour or intensity of the chromophore.
azlons	Generic term for regenerated protein fibres derived from a range of protein sources (milk, peanuts etc.).
azoic dyes	A form of dyes the chromophore of which is formed within the fibre from two components.
ball tops	Top wound into a ball for dyeing.
blocking agents	Colourless anionic compounds used in dyeing wool/polyamide blends which slow dyeing rates by blocking dye sites on the polyamide fibre.
bump tops	Top wound into large balls for dyeing.
carbonising	The process of removing vegetable matter from scoured wool or fabric using sulphuric acid.
cationic dyes	Dyes in which the dye molecule is positively charged, also called basic dyes.
centres	Yarn is wrapped around centres before dyeing. They can be cones, tubular or steel springs.

Term	Definition
channelling	The uneven flow of the dye liquor through the fibre mass.
chelating agent	A compound that complexes magnesium and sodium ions in water used during the dyeing process.
chromophore	The component of the dye molecule that gives colour to the dyestuff by selectively absorbing light in the visible region.
cockling	Fabric distortion caused by uncontrolled relaxation of the fabric, arising from inadequate setting during fabric preparation. Also known as 'crow's feet'.
crow's feet	An unwanted distortion of the yarn in the structure of the garment, resulting in surface distortion, also known as 'cockling'.
cuttle	The layering of fabric after a batch process.
delustering	Removal of lustre from a fabric, usually by chemical treatment.
disperse dyes	Finely dispersed, essentially water-insoluble dyes, which go onto (and into) the fibre from a dispersion in water. Developed for synthetic fibres that cannot be dyed easily with existing anionic or cationic dyes.
Donnan membrane effect	The behaviour of charged particles near a semi-permeable membrane that sometimes fail to distribute evenly across the two sides of the membrane.
exhaustion	The extent to which the dye transfers from the liquid to the fibre, measured as a percentage.
facing up	Surface fuzzing of primarily knitted garments, which can occur if mechanical action on the fabric surface is too high.
fastness	The ability of the dye to withstand the treatment the fibre undergoes in the processes after dyeing as well as in normal use and aftercare without changing colour or bleeding out of or rubbing off the fibres.
fixation	The formation of a stable interaction between the dye molecule and dye sites on the macromolecules of the fibre. The term is also used for any process than renders the dye molecule water insoluble within the fibre.
fly	Loose particles of dye powder that float in the air and which can deposit on inappropriate surfaces — also applied to fibre.
green vitriol	Ferrous sulphate, used as a mordant.

Term	Definition
grey scales	Grey-coloured cardboard squares used to measure colour differences and cross staining in dyed textiles.
hanks	Wool yarn wound up into long loops.
hygral expansion	The growth of a fabric as the fibres adsorb moisture.
leasing	The process of inserting ties into hanks to control the hanks during dyeing.
levelling agent	A reagent used to control the exhaustion of dyes to ensure level (even) dyeing; can affect the fibre, the hue of the dye or both.
levelness	The evenness of the distribution of the dye through the substrate.
light box	Colour-measurement cabinet.
loose fibre dyeing	Dyeing process where the liquor is pumped through the loose mass of the textile fibres.
mélange	A yarn of fabric made from a mix of different coloured fibres.
melanin	The colouring agent in pigmented wool.
migration	Movement of the dye molecule within the fibre.
miscible	Able to mix with (usually water).
mordant (noun)	A compound, commonly a metal salt (chromium, iron, aluminium) which complexes with the dye in the fibre to ensure the fastness of the dye.
mordant (verb)	The term used to describe the process of adding the mordant to the dyed fibre.
mordant dyes	These dyes are usually a small anionic molecule, which is complexed with a metal salt or with an organic compound after application to the fibre.
packages	Wool yarn wound onto centres for dyeing.
pad bleaching	A process of bleaching fabrics by passing fabric through squeeze rollers, which evenly apply the bleaching agent.
penetration	The movement of the dye molecule through the surface of the fibre.

Term	Definition
photo-bleaching	The bleaching of wool caused by exposure to sunlight.
photo-yellowing	The yellowing of wool caused by extended exposure to sunlight.
pigment printing	The application of a water-insoluble coloured pigment particle to the textile.
reactive dyes	Dyes that are generally anionic and chemically react with the polymer chains in the fibre.
running marks	Lengthwise creases formed in fabric during rope processes such as scouring, milling or piece dyeing, also known as rope marks.
shogging	The side-to-side action of the winding machine in package formation.
skitteriness	A term to describe differences in the colour and depth of the shade between and within fibres, refers to unlevel dyeing.
spectrophotometer	*An apparatus for measuring the intensity of light in the visual spectrum that is transmitted or reflected by particular substances.*
substantivity	The ability of the dye to be absorbed from the dyebath and retained by the fibre.
sulphonation	The substitution of a sulphonic acid group on the dye molecule.
superblacks	Intensely black colour required of fabrics used for formal occasions.
tippiness	Damage to the fibre from light and weather causing difference between the dyeing properties of the tip and the rest of the wool fibre, which leads to preferential adsorption of dyes.
transition metals	Elements of groups 4 – 11 in the periodic table.
trichromatic	Consisting of three colours
tristimulus values	The three reflectance readings (X, Y and Z) obtained when using a colourimeter, used in specifying the colour of wool including ecru wool.
vat-sulphur dyes	Dyes that are soluble in water containing a reducing agent under alkaline conditions, are applied to textiles from this solution by exhaustion and then oxidised to render them insoluble.

COURSE
INTRODUCTION

THE WOOLMARK COMPANY

THE DYEING OF WOOL

WELCOME participants as they arrive, ensuring they collect their pre-prepared name tags or ask them to write their name on a tag as they arrive.

ENSURE each participant takes a copy of the Participant Guide and records their attendance.

INTRODUCE yourself and provide a brief (maximum three-minute) overview of your role, experience and broad objectives in delivering this series of lectures.

After introducing yourself, if you have a group of 20 participants or less, ask each participant to provide a brief introduction (name, role and organisation, or area of study) and share three things they wish to achieve by attending this series of lectures.

NOTE: If you have 20 participants and they each take about 30 seconds to introduce themselves and their objectives, this exercise will require 10 minutes.

Keep it brief. You may need to modify your approach, based on the number of participants in the room. For example, in a large group (20+ participants select a small sample of participants to introduce themselves and share their expectations).

RECORD AND group participants' responses regarding their own learning objectives on the flipchart or whiteboard.

This introduction will expand upon your understanding of each participant's needs and attitude towards their participation in the program and will give them the opportunity to build rapport with you as the facilitator and other participants in the group.

EXPLAIN TO participants you will revisit these objectives throughout the course to ensure each objective has been covered or participants are directed to additional resources that will help them meet their own learning objectives.

Endeavour to draw on these participant objectives as you progress through the course.

SET UP guidelines for participant interaction by stating that if you ask a question of the audience, the correct answer is acceptable, the incorrect answer also is acceptable, however silence is unacceptable.

ENCOURAGE participants to ask questions by reassuring them that all questions are valuable.

SPEND a few moments exploring participants current understanding of wool. Establishing how much individuals, or the group as a whole, already know about wool will allow you to acknowledge and leverage the experience of those in the room and tailor the content and delivery of the course appropriately to either dispel misperceptions or build on current understanding.

ALLOW about 5–10 minutes for a group discussion prompted by a questioning approach outlined below.

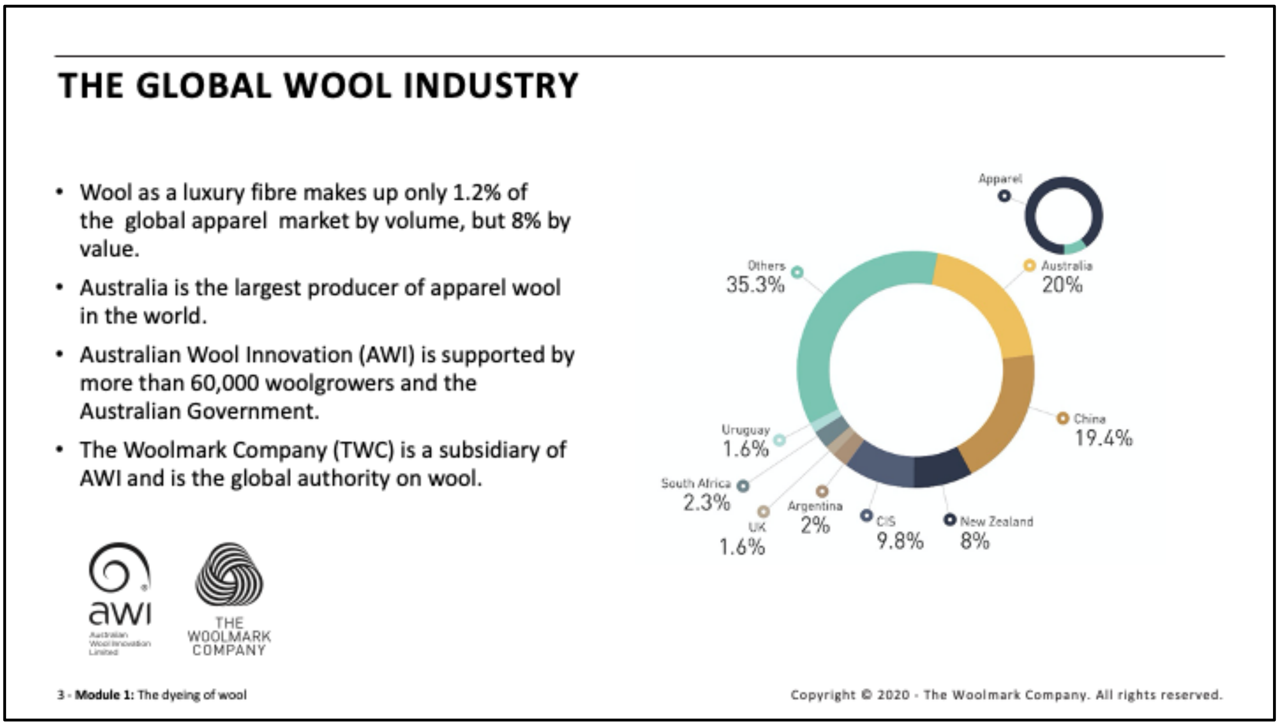
ASK *participants to share what they already know about wool dyeing*

Examples of questions you might ask to encourage participation include:

- *What is dyeing?*
- *Can you use the same dyes on wool and cotton?*
- *At what stages during processing can wool be dyed?*
- *What makes a 'good' dyeing?*

RECORD responses to the above questions on a flipchart or whiteboard and explain that you will re-visit the responses at the end of this module and the course to reflect upon what participants may have learnt during the course.

NOTE: If participants have not already been introduced to Australian Wool Innovation (AWI) and The Woolmark Company (TWC) insert this short presentation here, before continuing with *Module 1 — The process of dyeing.*



REFER TO the slide as you indicate that Australian woolgrowers produce 90% of the world's fine apparel wool as part of Australia's $2.5 billion wool export industry*.

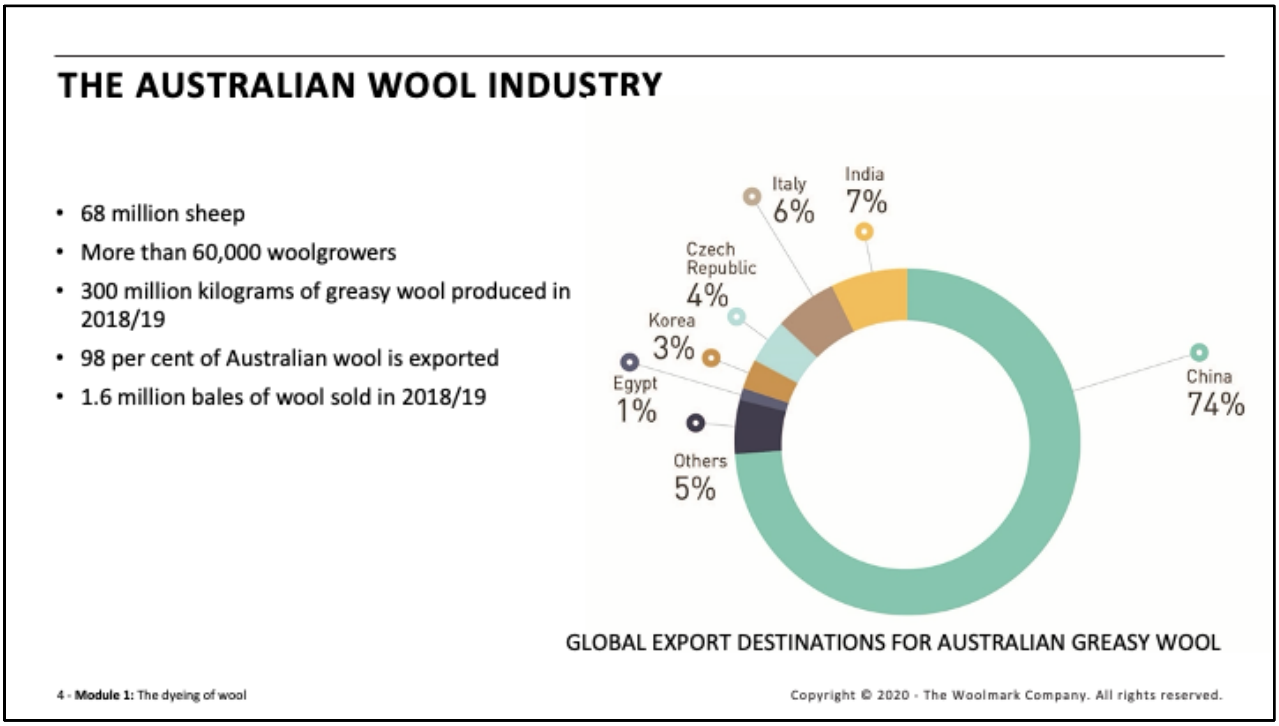
**Source ABARES Agricultural Commodities, March 2020 quarter.*

EXPLAIN THAT Australian Wool Innovation (AWI) is the research, development and marketing body for the Australian wool industry, supported by more than 60,000 Australian woolgrowers, who co-invest with the Australian government to support the activities carried out by AWI and TWC along the global wool supply chain.

EXPLAIN THAT The Woolmark Company is a subsidiary of Australian Wool Innovation and is a global authority on Merino wool. With a network that spans the entire global wool supply chain The Woolmark Company builds awareness and promotes the unique traits of nature's finest fibre.

REINFORCE THAT The Woolmark Company collaborates with global experts on all aspects of wool science, technology and design to develop and deliver educational materials, such as the course you are about to deliver.

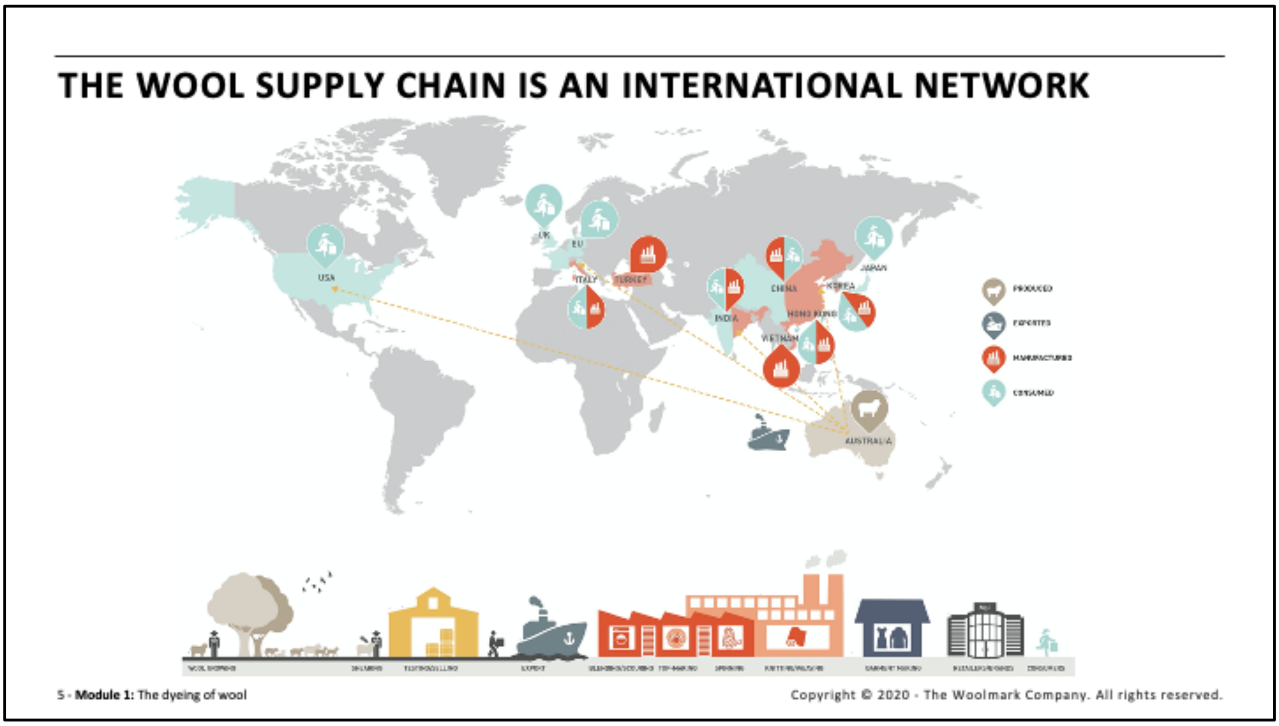
NOTE THAT you will provide a brief overview of the Australian wool industry and global supply chain, and elaborate on the role of The Woolmark Company in the global context before commencing the technical components of the course



EXPLAIN THAT there are more than 68 million sheep in Australia, carefully managed by more than 60,000 woolgrowers.

INDICATE THAT in 2018/19 Australia's woolgrowers produced 300 million kilograms of greasy wool and sold 1.6 million bales of wool.

POINT OUT that 98 per cent of Australia's wool is exported to other countries for further processing into a diverse range of products.



REFER TO the slide as you explain that it offers a snapshot of the global dynamics of the Australian wool industry, illustrating where the key export markets are for Australian wool, where most wool is processed from its raw state into yarn and fabrics and where the fashion and trend influencers and wool consumers are located.

NOTE THAT countries such as China, India and Italy are major manufacturers and consumers of wool products.

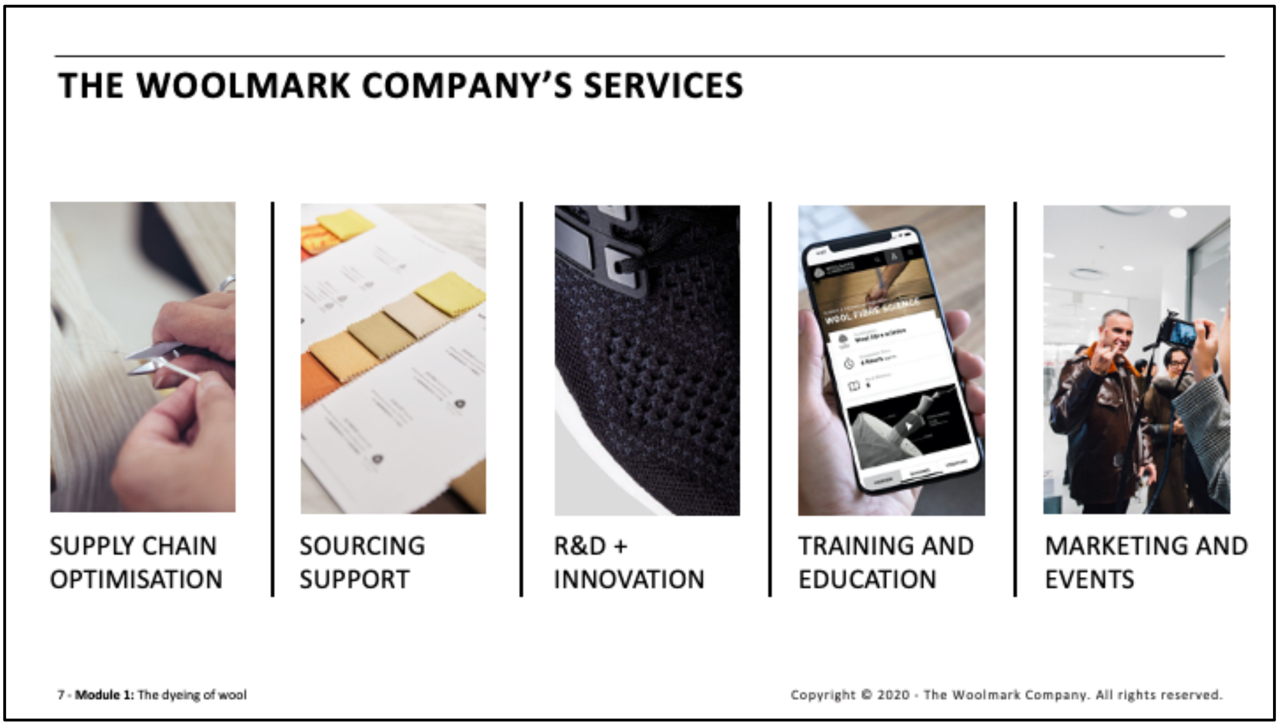
EXPLAIN THAT in line with these global dynamics, The Woolmark Company head office in Sydney, Australia is supported by a growing number of regional offices globally. Through this support The Woolmark Company invests in innovation along the global wool supply chain.

REINFORCE THAT The Woolmark Company works on behalf of Australia's 60,000+ woolgrowers, who are responsible for producing 90 per cent of the world's fine apparel wool.

EXPLAIN THAT The Woolmark Company's parent body — Australian Wool Innovation — invests in on-farm research and development to deliver new knowledge to woolgrowers to increase the profitability and sustainability of the growing wool business.

NOTE THAT The Woolmark Company strives to deliver tangible solutions across the global wool textile industry through process and product research and development.

EXPLAIN THAT the Woolmark Company builds industry confidence through communication, collaboration and a range of educational programs across the industry.



EXPLAIN THAT The Woolmark Company partners with designers, brands and retailers worldwide, offering support with quality assurance, product innovation and supply chain assistance.

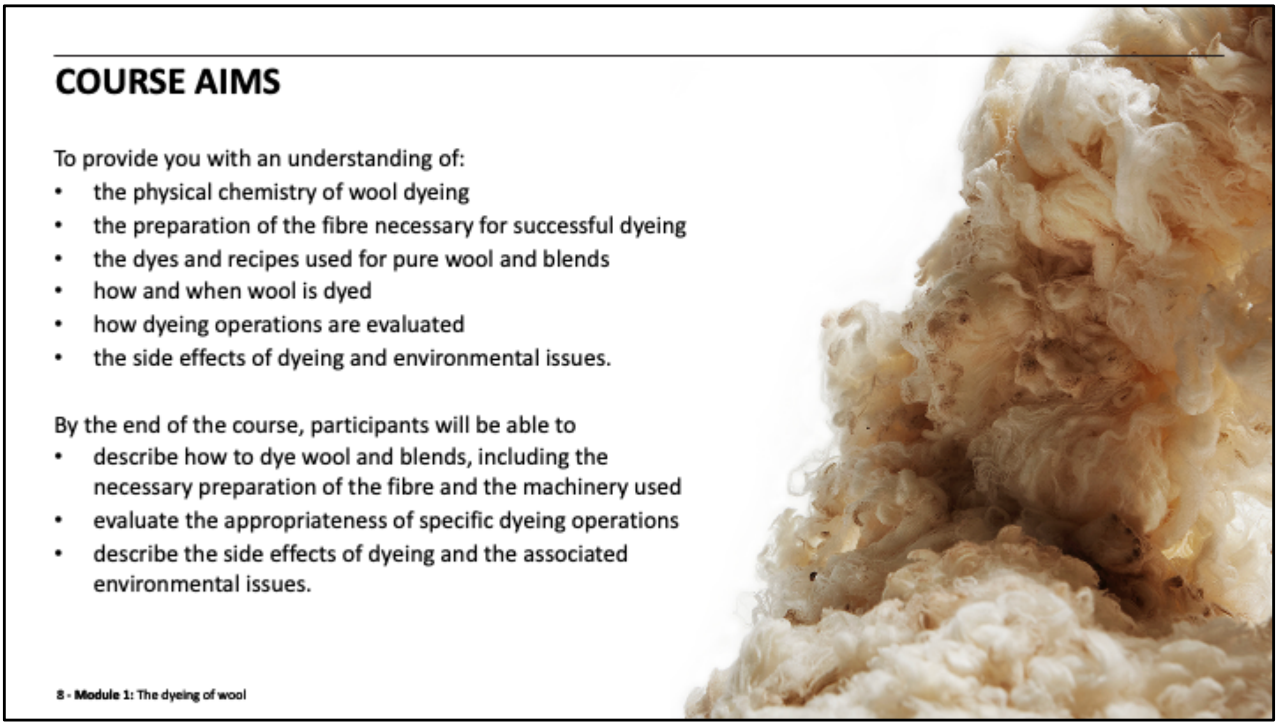
INDICATE THAT The Woolmark Company provides sourcing support through direct access to the global wool manufacturing industry through The Wool Lab. A seasonal guide to the latest innovations in wool, fabrics are sourced from the world's best spinners and weavers in the global supply network.

REINFORCE THAT The Woolmark Company takes secures funding and delivers research to improve wool production and processing through fibre science, traceability and fibre advocacy.

EXPLAIN THAT The Woolmark Company offers a range of online and face-to-face training programs to educate the industry. During 2019, The Woolmark Company launched the Woolmark Learning Centre, an online educational hub for industry professionals.

POINT OUT that The Woolmark Company markets the performance and environmental benefits of the fibre to ensure industry and consumers are informed and inspired to make better purchasing choices.

ASK PARTICIPANTS if they have any questions about the Woolmark Company before you proceed with the course aims.



INDICATE THAT the aim of the course is to provide participants with:

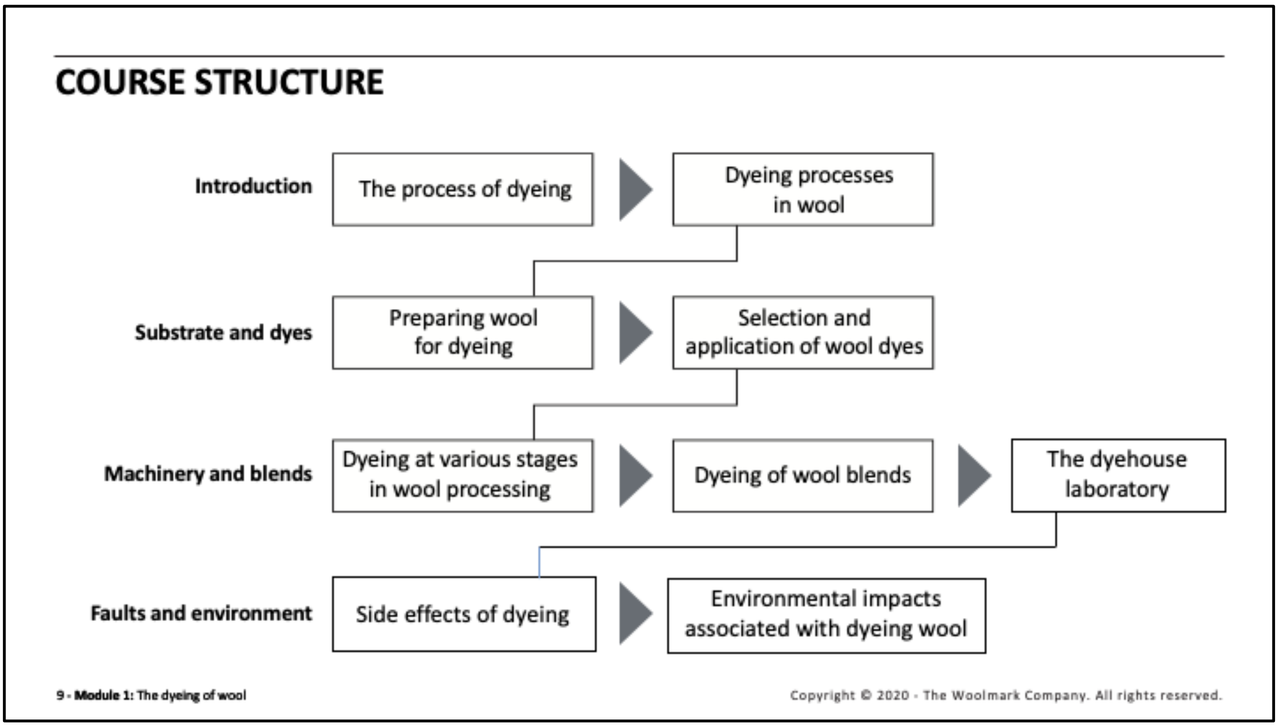
- an understanding of wool dyeing
- knowledge on how and when wool is dyed
- information on how the fibre is prepared for dyeing and evaluated after dyeing.

NOTE THAT in particular participants will learn about:

- the chemistry of wool dyeing
- the preparation of the fibre necessary for successful dyeing
- the dyes and recipes used for pure wool and blends
- how and when wool is dyed
- how dyeing operations are evaluated
- the side effects of dyeing and associated environmental issues.

INFORM participants that by the end of the course they will be able to:

- describe how to dye wool and blends, including the necessary preparation of the fibre and the machinery used
- evaluate the appropriateness of specific dyeing operations
- describe the side effects of dyeing and the associated environmental issues.



EXPLAIN THAT the modules covered in this course include:

An introduction to:
- the process of dyeing
- the dyeing processes in wool

The wool substrate and dyes:
- Preparation of wool for dyeing
- Selection and application of wool dyes

Dyeing machinery and recipes
- Dyeing at various stages in wool processing
- Dyeing of wool blends
- The dyehouse laboratory

Faults in dyeing and environmental issues
- Side effects of dyeing
- Environmental issues

MODULE 1

THE WOOLMARK COMPANY

THE PROCESS OF DYEING

RESOURCES — MODULE 1: THE PROCESS OF DYEING

Contained in *The dyeing of wool* Demonstration kit you will find the following resources for use as you deliver **Module 1: The process of dyeing**:

- sample of wool top
- sample of cotton fabric

Additional resources to be sourced by the facilitator include:

- bottle of vegetable dye
- bottle of acid (dilute)
- beaker of hot water
- beaker of cold water
- glass stirring rod
- wetting agent

EXPLAIN THAT this module reviews the processes involved in dyeing of textile fibres.

EXPLAIN THAT by the end of this module participants will be able to:

- outline the aims of the textile dyeing process
- explain how textiles are dyed
- outline the physical chemistry of dyeing
- differentiate between natural and synthetic fibres
- explain the use of natural and synthetic dyes
- describe the interaction between dyes and fibre types
- explain fibre chemistry in relation to dye sites,
- describe the concepts of circulation and affinity
- understand the importance of levelness and migration
- describe substantivity and fixation of dyes
- describe the processes employed to improve dye fastness.

INDICATE THAT in later modules the course will focus on these processes specifically in the wool fibre.

RESOURCES REQUIRED FOR THIS MODULE

- beaker of cold water (facilitator to provide)
- beaker of hot water (facilitator to provide)
- bottle of vegetable dye (facilitator to provide)
- bottle of acid (dilute) (facilitator to provide)
- wetting agent (facilitator to provide)
- glass stirring rod (facilitator to provide)
- sample of wool fabric
- sample of cotton fabric
- *rinsewater* (facilitator to provide)
- *containers to hold dye liquor* (facilitator to provide)
- *container to hold rinsewater* (facilitator to provide)
- *tongs to extract fabric from dye liquor and rinsewater* (facilitator to provide)

DEMONSTRATION: THE PROCESS OF DYEING

NOTE TO FACILITATOR: *Set up the following demonstration at the start of the lecture. Participants will be asked to observe the results at the end of the lecture.*

Resources required:

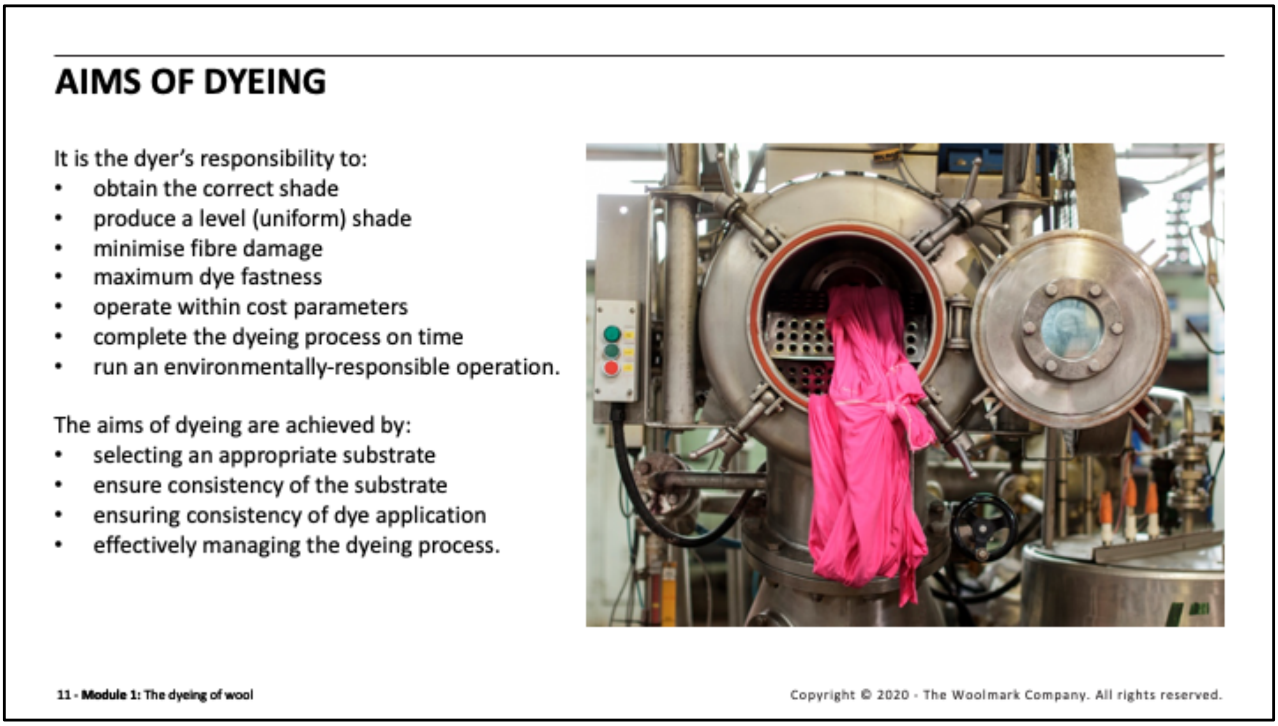
- beaker of cold water
- beaker of hot water
- bottle of vegetable dye
- bottle of acid (dilute)
- wetting agent
- glass stirring rod
- sample of wool fabric
- sample of cotton fabric

ADD *a small amount of vegetable dye and a little wetting agent to the beaker of cold water.*

ADD *a small amount of vegetable dye and a little acid (dilute) and wetting agent to the beaker of hot water.*

PLACE *samples of wool fabric and cotton fabric into both beakers, stirring each beaker with the glass stirring rod until the samples are wet out.*

LEAVE *the beakers in place until the end of the lecture.*



INDICATE THAT to manage a successful and profitable dyeing operation, the dyer must:

- obtain the correct shade
- meet customer requirements for levelness (uniformity of shade)
- meet product requirements in terms of damage and fastness
- operate within cost limits
- complete the dyeing process on time
- have an environmentally-sustainable operation.

EXPLAIN THAT these aims are achieved by checking and controlling:

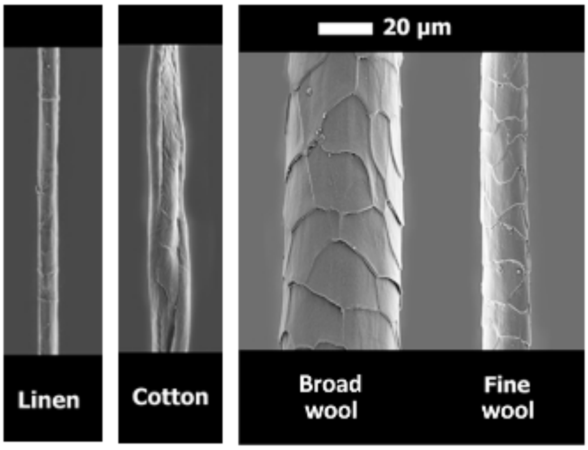
- the type of the substrate (Note that with synthetics, not all polyamides are the same, nor are acrylics. The same applies to wool – not all wool is the same.)
- the consistency of the substrate, which involves an understanding of and appreciation for:
  - the history and preparation of the substrate
  - fibre diameter and related considerations
  - the nature of any chemical pre-treatment
  - fibre pH
  - fibre blend composition.
- the consistency of dyestuff application, which is affected by:
  - the concentration of the chromophore
  - the moisture content of the dyestuff
  - weighing and solution techniques
- the consistency of the process, which is affected by the:
  - liquor/goods ratio (the ratio of the volume of water used in the dyebath to the weight of the textile material to be dyed)
  - dyebath pH (acidic or basic)
  - liquor flow — circulation in the machine
  - time and temperature profile — correct rate of heating
  - appropriate auxiliaries. (Auxiliaries is the term used to describe all the additional materials added to the dyebath to assist the dyeing process. These vary in nature and function and will be discussed later in this course.)

FIBRE TYPES — NATURAL FIBRES

Cellulosic fibres
- cotton, linen, sisal, hemp etc.
- a polysaccharide
- uniform chemical composition
- considerable macro-structural heterogeneity.

Protein fibres
- animal hairs (e.g. wool, cashmere, etc.)
- complex co-polymers of amino acids (primarily keratin)
- considerable chemical heterogeneity between the structural components.

Silk
- morphologically and chemically simpler than animal hair.



12 - Module 1: The dyeing of wool

NOTE THAT textile fibres can be categorised into three main groups:
- natural fibres
- man-made fibres
- synthetic fibres.

Natural fibres

There are two major subgroups of natural fibres — cellulosic (or plant) fibres and animal fibres, examples of which are included on the slide.

Cellulosic fibres include cotton, linen, hemp, etc. These are primarily composed of cellulose (a polysaccharide) and small amounts of lignin.

Animal fibres are proteinaceous materials composed of a large number of complex co-polymers formed from amino acids.

Animal hairs (such as wool, alpaca and cashmere) consist primarily of keratin.

NOTE THAT silk is a proteinaceous filament created by the silkworm larvae. Silk is the only animal fibre that is not an animal hair. The morphology of silk is quite different to that of animal hairs. There are significant differences in the chemistry of silk proteins from those found in animal hair.

EXPLAIN THAT with the exception of silk, both types of natural fibre (cellulosic and animal) have considerable heterogeneity in the structure of the fibre and, in the case of protein fibres, the chemistry of the components.

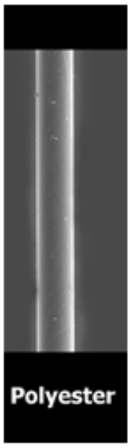
POINT OUT that more detail on the structure, physics and chemistry of wool and other animals fibres is covered in the Wool Science, Technology and Design Education Program course *Wool fibre science*.

MAN-MADE AND SYNTHETIC FIBRES

Man-made and synthetic fibres:

- Are relatively uniform composition.
- Have little macro-structural variation within the fibre.
- Man-made fibres include:
  - regenerated cellulose (Rayon, Tencel etc.)
  - cellulose derivatives—– chemically like cotton
  - regenerated protein (Azlon) — chemically-like similar to wool, but with a different physical structure.
- Synthetic fibres include:
  - nylons — polyamides (nylon 6, nylon 6,6)
  - polyesters _ esters of terephthalic acid (aromatic)
  - acrylics — copolymers of acrylonitrile
  - polylactic acids.

The cross-sectional shape of synthetic fibres is determined by the manufacturer.



13 - Module 1: The dyeing of wool

EXPLAIN THAT man-made fibres are generally re-constituted natural polymeric materials. These fibres include:

- **Rayon and Tencel** are cellulosic fibres manufactured using re-constituted wood cellulose
- **Ardil** is derived from ground nut protein
- **Lanital, Merinova, Protilon** and **Aralac** are fibres derived from milk protein (casein)
- **Vicara** was manufactured from zein, derived from corn.

Azlon is the common generic name for all man-made protein fibres.

NOTE THAT these fibres are chemically similar to the natural fibres they imitate, but are structurally quite different.

Man-made protein fibres are much more homogeneous in structure and chemical composition.

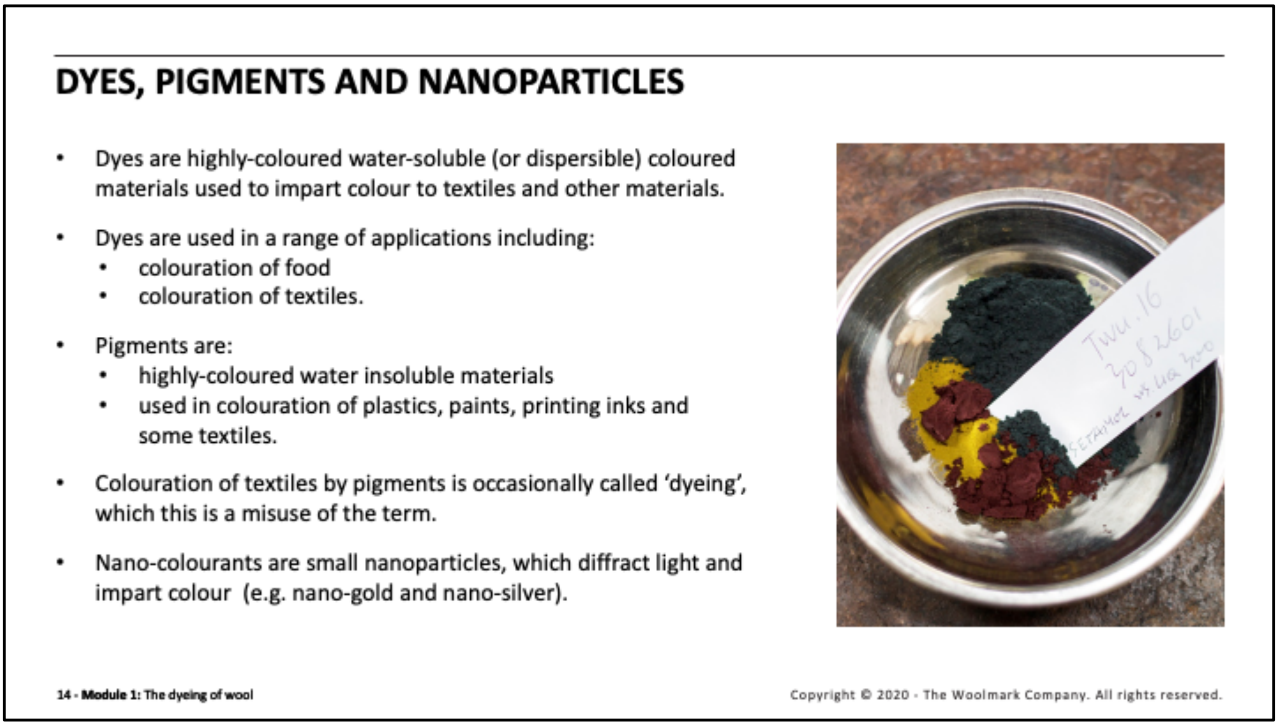
EXPLAIN THAT synthetic fibres are generally polymers created from oil-based source materials.

Polyamides, polyesters and acrylics are often co-polymers derived from a major and minor component of the source materials.

Small variations in the chemistry of the fibre type results in quite different dyeing behaviour and performance.

The shape of synthetic fibres is often cylindrical (as shown on the slide), but fibres with special cross-section shapes have been developed for specific end uses.

NOTE: Recently some fibres have been developed using polymers manufactured using chemicals derived from natural products like corn starch. These are still synthetic polymers as the polymer chains are synthesised from the component chemicals.



EXPLAIN THAT dyes are highly-coloured water-soluble (or dispersible) materials that transfer from aqueous solution into textiles and other materials imparting colour. They are used across a range of applications, from colouration of food to the colouration of textiles.

NOTE THAT there is a wide range of commercial dyes used for textiles. Different dyes are required for each of the possible fibres and fibre combinations. Different types of dye are normally used for different fibre types, although some dyes will successfully dye more than one fibre type.

The quality of dyes, in terms of shade, strength and technical performance, varies between dye types and different suppliers.

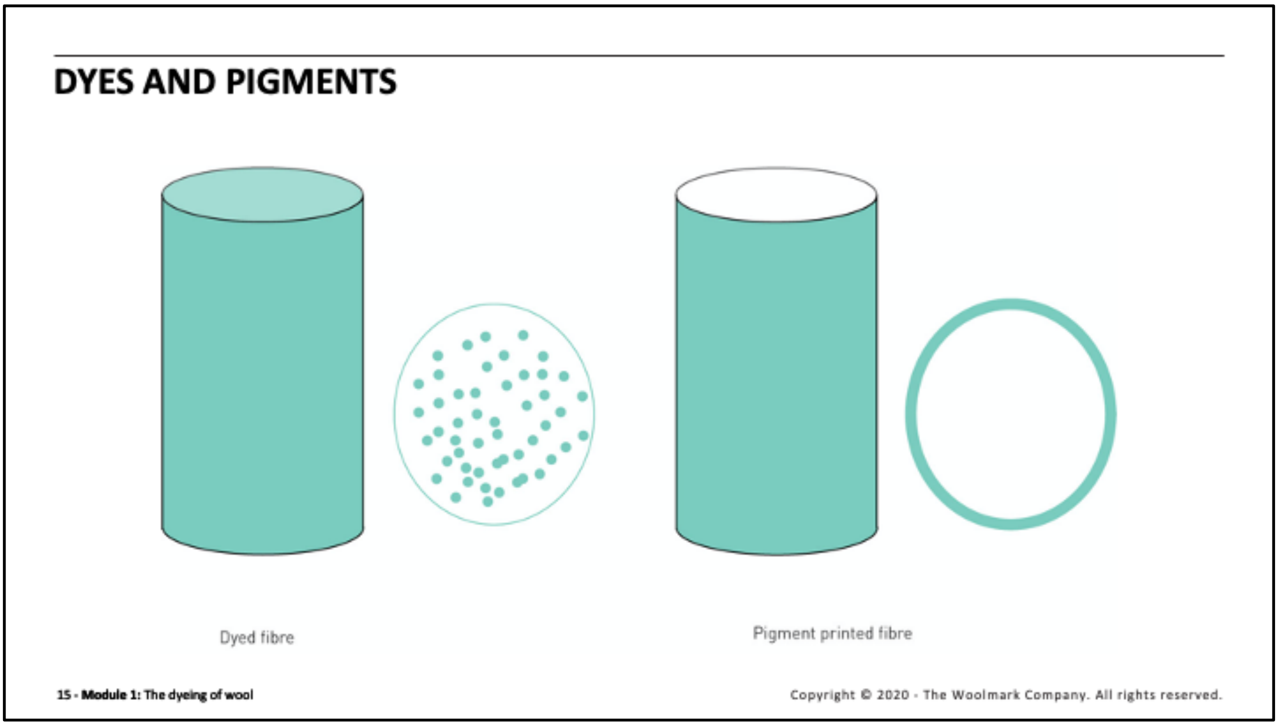
EXPLAIN THAT pigments are highly-coloured water-insoluble materials used to impart colour to plastics, paints printing inks and some textiles.

Pigment particles are normally dispersed in the polymeric medium, giving it colour.

NOTE: Imparting colour to textiles using pigments is occasionally called 'dyeing', but this is a misuse of the term. When pigments are used to colour textiles, they are generally deposited in the surface of the fibre (as opposed to being adsorbed by the fibres themselves).

POINT OUT that some small nanoparticles can impart colour to polymeric materials onto which they are adsorbed. These materials are in the form of tiny particles and appear coloured because they diffract light in the visible range. There is no chromophore that selectively adsorbs colours, colouration is achieved by selective diffraction of light.

Nano-colourants can be used to colour wool and cotton. Typically nano-sized gold or silver particles have been used for these purposes.



REITERATE THAT building on the information just covered in the previous slide, textiles may be coloured in a number of ways.

Dyeing involves penetrating the fibre with coloured molecules so, in the ideal case, the coloured dye molecules are evenly distributed throughout the fibre.

Pigment printing involves the application of a water-insoluble coloured pigment particle to the textile. The pigment deposits on the surface of the fibre, coating the fibre, but not entering the fibre. The pigment forms a coloured coating on the surface of the fibre.

Nano-colourants, which are not inherently coloured, can also be printed or exhausted from long liquors onto textiles. These materials include colloidal gold and colloidal silver. Like pigments, nan-colourants also deposit on the surface of the fibre, but do not significantly penetrate the fibre.

Printing textiles with water-soluble dyestuffs is a ‘dyeing process’. After the dyes are printed onto the surface of fibres, the textile is treated to ensure the dye molecules migrate into the fibre.

NATURAL AND SYNTHETIC DYES

- Before 1853 all dyes were natural, extracted from plants and animals
  - Mordants were also used to give the dyes a different colour and greater fastness
- Certain colour and dyes developed religious or social significance
  - Tyrian Purple extracted from sea snails
- The first synthetic dye was 'mauveine', discovered by William Perkin in the UK in 1856
  - Many other synthetic dyes quickly followed
  - Much deeper colours
  - More reliable and reproducible colourants than natural dyes
- Natural dyes are still used in craft industries and by some small commercial enterprises

https://drnsg.wordpress.com/2013/05/10/the-history-of-color-revolution-mauveine-and-indigo/

http://lilyabsinthe.com/2015/06/11/and-for-a-little-more-mauveine/

16 - **Module 1:** The dyeing of wool

NOTE THAT the earliest use of colour by humans was observed in cave art.

EXPLAIN THAT samples of dyed textiles from Central European lake villages dates from 4000 to 3000 B.C.E. These peoples used blue, red, lilac and yellow dyes derived from plant and aquatic animal sources to impart colour to natural fibres.

POINT OUT that in ancient Egypt, natural dyes were also used and there is evidence of alum being used to 'mordant' or 'fix' the natural dyes more permanently to the textiles after the dye had been applied. It was known, even at this time, that without mordanting the natural, organic dyes used generally had poor 'fastness' properties.

Synthetic dyes were developed during the second half of the 19th Century. The first synthetic dye was 'mauveine', discovered by William Perkin in the UK in 1856 as shown on the slide.

INDICATE THAT many other synthetic dyes quickly followed, based on alizarin, azo compounds and sulphur compounds.

EXPLAIN THAT synthetic dyes gave better colour depth and fastness than their natural counterparts and were more reliable and reproducible colourants than natural dyes.

Natural dyes are still used in craft industries and by some small commercial enterprises, but the volume is small.

CHROMOPHORES

Functional groups that by themselves absorb visible or near UV radiations (electron acceptors).

Azo group	–N=N–
Nitro group	$–NO_2$
Carbonyl group	–C=O
Alkyl ammonium	$–NR_3^+$

AUXOCHROMES

Saturated functional groups with non-bonding electrons on an atom attached to a conjugated system (electron donor).

Amino group	$–NH_2$
Mono alkyl amino group	–NHR
Dialkyl amino group	$–NR_2$
Hydroxyl group	–OH
Ether group	–OR

17 - Module 1: The dyeing of wool

INDICATE THAT dye molecules usually have four components :

- chromophore
- auxochrome
- solubilising group
- hydrophobic region.

EXPLAIN THAT the chromophore gives colour to the dyestuff by selectively absorbing light in the visible region. Typical chromophores include azo groups, nitro groups, carbonyl groups and alkyl ammonium groups (as outlined on the slide). In most dyes (and pigments), chromophores are part of extended conjugated systems in which there are delocalised electrons within the group. The 'chromophores' listed on the slide are groups commonly found in conjugated systems, but are not themselves solely responsible for the absorption of visible light.

NOTE THAT the auxochrome modifies the colour or intensity of the chromophore. Typical auxochromes include amino, alkyl amino and hydroxy groups (as outlined on the slide).

SOLUBILISING GROUPS

Anionic (used in anionic dyes)

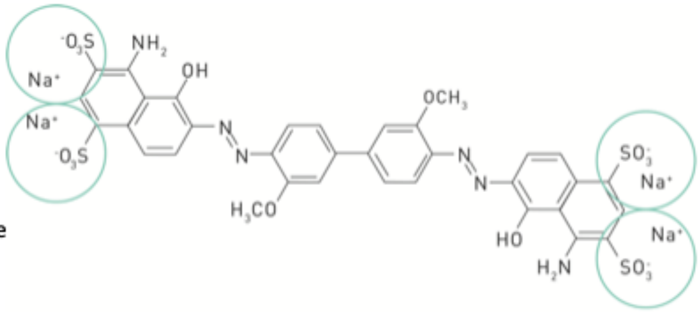
- $–SO_3Na$
- $–COONa$

Basic (used in cationic dyes)

- $–NH_3^+Cl^-$
- $–NR_3^+Cl^-$

Polar (in weakly water-soluble disperse dye

- –OH
- $–NH_2$
- $–SO_2NH_2$



Direct blue 1

EXPLAIN THAT the solubilising group confers water solubility to the dyestuff molecule. Some of the groups used to confer solubility to dye molecules are shown in the slide using the example of the Direct blue 1 dye.

INDICATE THAT typically, sulphonic acid groups (circled on the slide) are used for anionic dyestuffs (negatively-charged molecules). Carboxyl groups are also used.

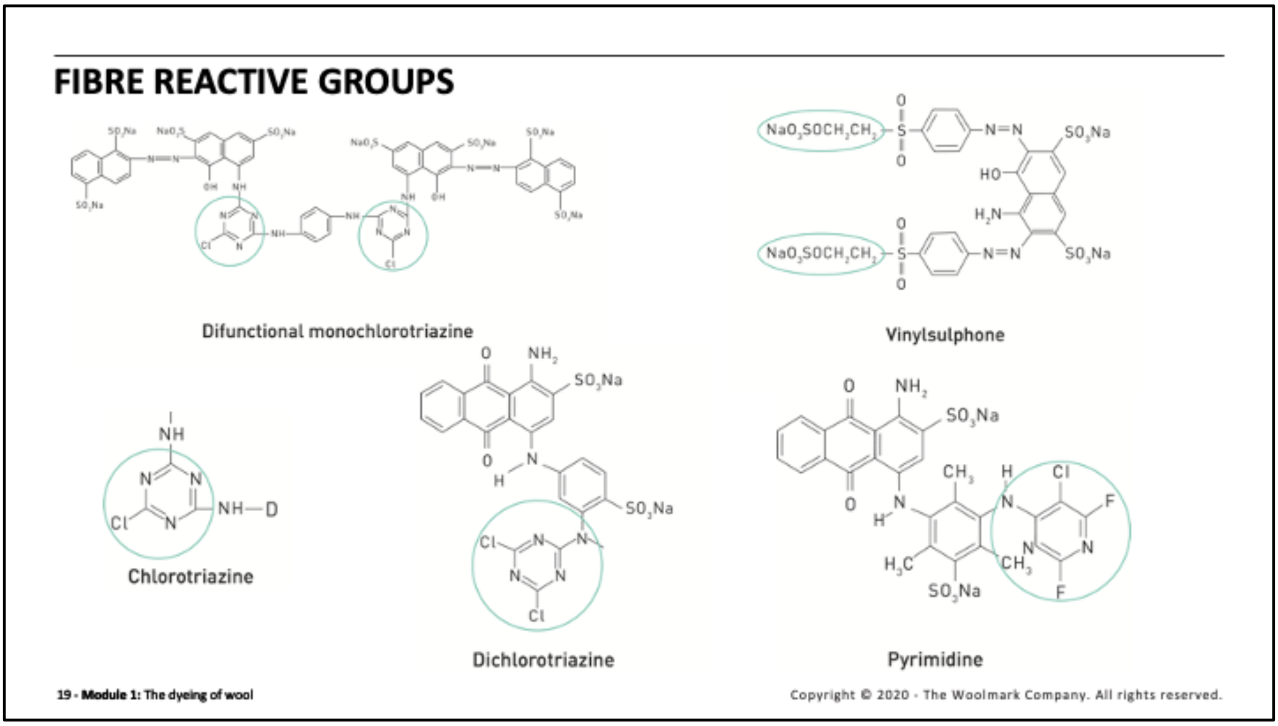
For cationic dyestuffs (positively-charged molecules), substituted ammonium groups are most common.

EXPLAIN THAT for some synthetic fibres disperse dyes are used, which are not water soluble but can be dispersed as small enough particles that they will enter the fibre. Such dye molecules contain polar groups, which assist in dispersing the dye.

NOTE THAT most dye molecules also have a **hydrophobic component.** This part does not prevent solubilisation of the dyestuff but is important in conferring affinity of the dye for the substrate. Affinity is the measure of the attraction between the fibre and the dye.

POINT OUT that the balance between the hydrophilic character (due to solubilising groups) and the hydrophobic character (due to hydrophobic groups) affects:

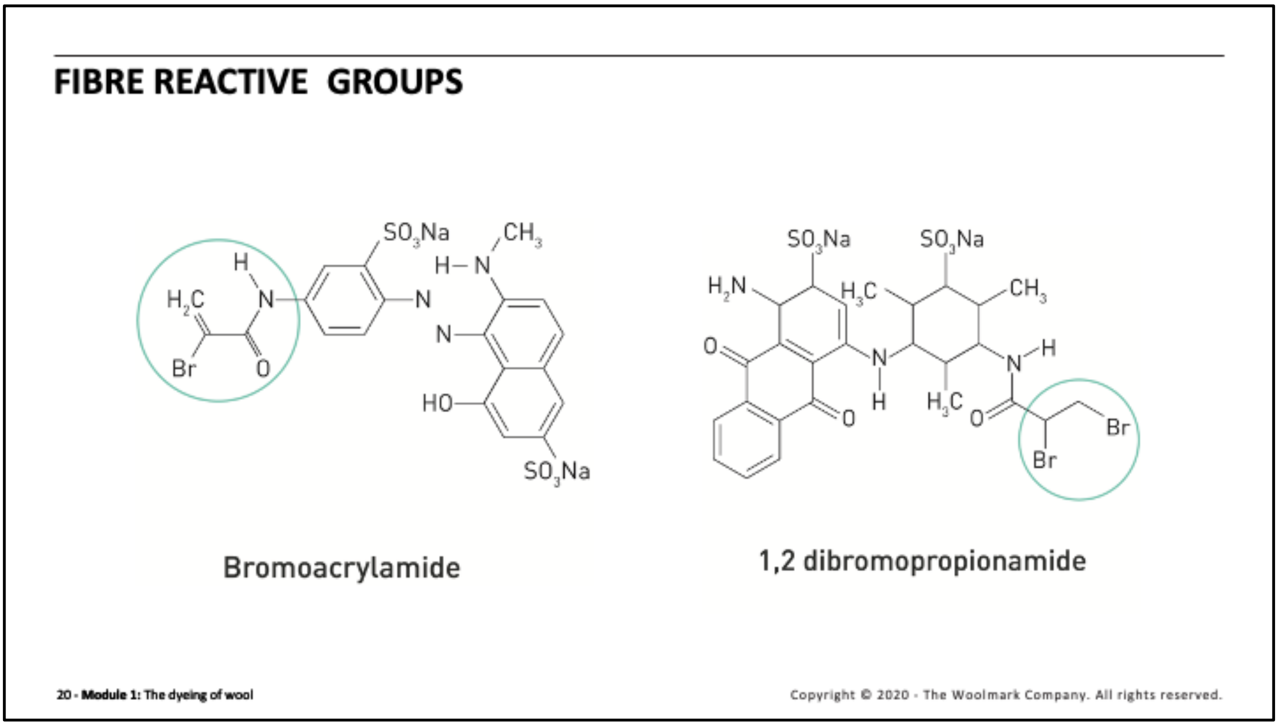
- the ease of solubilisation of the dye
- the rate of dyeing
- the wet fastness of the dye.



REMIND participants that as outlined earlier, certain types of dyestuffs can form chemical bonds (react) with the fibre molecules. These are generally called reactive dyes and are widely used on natural fibres.

NOTE THAT as illustrated on the slide, the typical reactive groups (shown in the rings on each diagram) in the dyestuff molecule include:

- chlorotriazine and dichlorotriazines
- fluoro-pyrimidines
- activated vinyl groups (vinylsulphone).



INDICATE THAT this slide shows two examples of another type of group used to react with the fibre molecules:

- bromoacrylamide
- 1,2 dibromopropionamide.

DYES AND DYE TYPES

Anionic
- The dye molecule is (negatively) charged.

Cationic (basic dyes)
- The dye molecule is (positively) charged
- Called *basic dyes.*

Reactive
- The dye molecule reacts with the polymeric chains within the fibre.

Mordant
- The dye molecule complexes with a metal ion or other compound after it has been applied to the fibre.

21 - Module 1: The dyeing of wool

EXPLAIN THAT there is currently a range of synthetic dye types offering a spectrum of colours suitable for a wide range of fibre types.

Anionic dyes
The dye molecule in an anionic dye, as the name suggests, is (negatively) charged.

There are several types of anionic dyes including:
- direct dyes used on cellulosic (plant-based) fibres
- acid dyes (four types) used for dyeing protein and nylon fibres —normally applied under acid conditions and discussed later in depth
- metal-complex dyes used used for dyeing protein and nylon.

Cationic dyes
The dye molecule is (positively) charged.
These dyes are:
- also called *basic dyes*
- normally applied under basic (alkaline) conditions
- often brilliant in colour
- generally used on acrylics.

Reactive dyes
Reactive dyes are generally anionic and chemically react with the polymer chains in the fibre.
Different types of reactive groups are used for different fibres:
- For cotton — a chlorotriazine group is commonly used.
- For wool — an activated alkene is often used.

Mordant dyes
Mordant dyes are usually a small anionic molecule, which is complexed with a metal salt or with an organic compound after application to the fibre.

DYES AND DYE TYPES

Vat and sulphur dyes
- The dye molecule is water soluble in reduced form, but oxidises in air to an insoluble form.

Disperse dyes
- The dye molecule has limited solubility in water, but is dispersible and will exhaust onto fibres.

Developed dyes
- Dyes in which the 'chromophore' is formed within the fibre (e.g. azoic dyes).

Analine black

22 - Module 1: The dyeing of wool

EXPLAIN THAT in addition to the aforementioned water-soluble dyes, there are other dye types, the ionic character of which changes during dyeing.

Vat and sulphur dyes

Vat and sulphur dyes are soluble in water containing a reducing agent and under alkaline conditions. They are applied from this solution by exhaustion (this process will be covered shortly). Oxidation in air renders the dye insoluble.

NOTE THAT there are two classes of vat dyes, derived from:
- indigo
- anthraquinone.

Disperse dyes

INDICATE THAT disperse dyes are:
- finely dispersed, essentially-water-insoluble materials, which go onto (and into) the fibre from a dispersion in water
- developed for synthetic fibres that cannot be dyed easily with existing anionic or cationic dyes.

Developed dyes — azoic dyes

EXPLAIN THAT azoic dyes are the most common form of developed dyes. They are formed within the fibre from two components. These dyes generally have excellent wet fastness properties, however there are major concerns over the toxicity of the starting materials and resultant dyes.

Analine black

INDICATE THAT analine black dyes are:
- applied as hydrochloride
- oxidised with potassium dichromate under acid conditions to form large molecules, which contain an intense black chromophore.

THE PROCESS OF DYEING

Dyeing is the process in which a coloured material (dye), dissolved (or dispersed) in water, is transferred to a textile fibre to impart colour to that fibre.

The process is called '*exhaustion of the dye*'.

The extent to which the dye transfers from the liquid to the fibre is called the '*degree of exhaustion*'.

The stages of dyeing are:

- approach
- adsorption
- penetration
- migration
- fixation.

23 - **Module 1:** The dyeing of wool

TO RECAP — dyeing is the process in which a coloured material (dye), is dissolved (or dispersed) in water and transferred to a textile fibre to impart colour to that fibre.

EXPLAIN THAT the process is called 'exhaustion of the dye'. The extent to which the dye transfers from the liquid to the fibre is called the 'degree of exhaustion'. Exhaustion is described in percentage terms — 100% exhaustion means all the dye has gone from the dyebath into or onto the fibre.

NOTE THAT the stages of dyeing are

- approach
- adsorption
- penetration
- migration
- fixation.

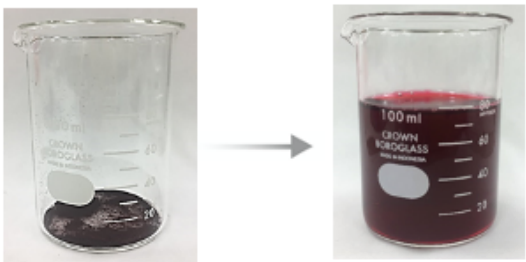
EXPLAIN THAT these processes can all occur at different rates. The rate-determining step will vary for different dyes and fibres.

Each step is discussed in the following pages.

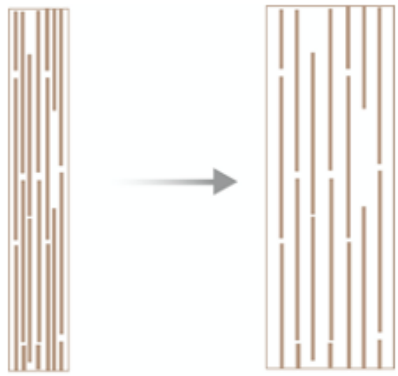
THE ROLE OF WATER IN DYEING

Water dissolves the dyestuff, reducing the size of the molecular aggregates to dimensions that can enter the fibre.

Auxiliaries are used to:
- aid solubilisation
- aid de-aggregation and/or dispersal of the dyestuff.



For hydrophilic fibres (wool cotton etc) water causes the fibre to swell, allowing the dye molecules to more easily enter the fibre.



24 - **Module 1:** The dyeing of wool

NOTE THAT water is the medium most commonly used for dyeing. It has two roles:
- dissolving or dispersing the dyestuff
- swelling the textile fibres.

ASK *participants to estimate how much water causes the wool fibre to swell.*

ALLOW *sufficient time for participants to respond.*

ACKNOWLEDGE *responses and reinforce that the wool fibre will swell by ~16% from dry to wet.*
- *Cotton will swell by ~21% from dry to wet*
- *Viscose can swell by 25-50% from dry to wet*

EXPLAIN THAT the dyestuff is dissolved (or dispersed) in water, which reduces the size of the aggregates to mono-molecular courses or aggregates of a small number of molecules, depending on the water solubility of the dye and its hydrophilic–hydrophobic balance. This action allows more rapid penetration of the fibre by the dye molecules.

INDICATE THAT auxiliaries are used to aid the solubility of dyes with limited or poor solubility in water and to disperse water-insoluble dyes and maintain a small particle size. Examples include:
- Albegal products from Huntsman
- Lyogen products from Novartis.

EXPLAIN THAT as mentioned, some dyestuffs (dispersed dyes) have poor water solubility and are dispersed in the water as small aggregates using surface active agents .

The water swells the hydrophilic fibres, such as protein and cellulosic fibres, again allowing easier penetration of the fibre by the dye molecules.

POINT OUT that organic solvents can be used to dye fibres, but are less effective than water on the hydrophilic natural fibres as they do not swell the fibres as effectively.

The use of solvent dyeing is limited by the cost and toxicity of the solvent.

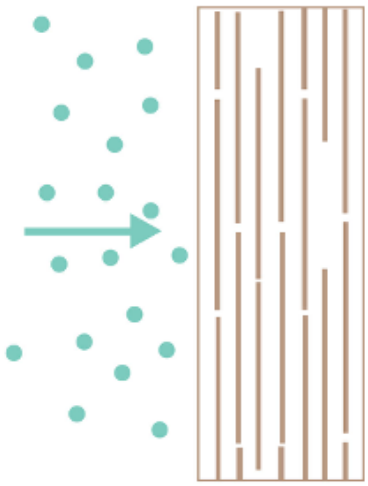
Some synthetic fibres can be dyed using super critical or liquid carbon dioxide.

EXPLAIN THAT mixtures of solvent and water can be used to more effectively swell the natural fibres, but again their use is limited by the cost and toxicity of the solvent.

APPROACH

The movement of the dye molecules in the dye solution (dye bath) towards the fibre.

- Circulation of the dyebath must be controlled.
- Sufficient circulation is essential to ensure ‘equal access’ to the dye solution by all the fibres.



25 - Module 1: The dyeing of wool

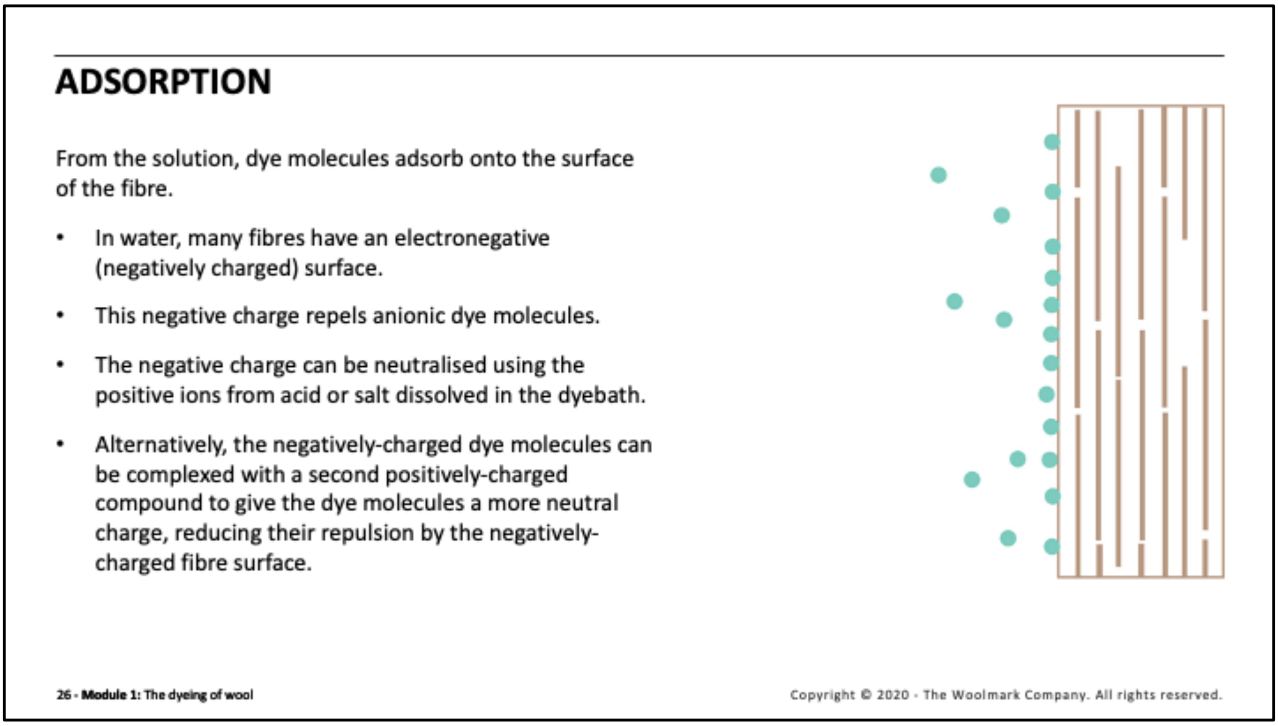
INDICATE THAT in the ‘approach’ stage of the dyeing process, dyes are dissolved in the dyebath, which is evenly circulated through the fibres.

EXPLAIN THAT the dye molecules are brought into contact with the fibre surface (for which they have some affinity) by the motion (circulation) of the dyebath.

In some forms of dyeing, the liquor is pumped through the mass of the textile fibres (e.g. loose fibre dyeing).

POINT OUT that in other forms of dyeing (e.g. fabric and garment dyeing) the textile is moved through the liquor.

NOTE THAT a uniform approach by the dye molecules to all the fibres requires even circulation of the liquor or the textile material through the liquor.



POINT OUT that from the solution, dye molecules adsorb onto the surface of the fibre.

NOTE THAT any irregularity of the surface of the fibres increases the specific surface area and aids adsorption of the dye.

EXPLAIN THAT when using anionic dyes, the negative charge that develops on the surface of most fibres in water must be limited by neutralisation with cations. Auxiliaries are used during the adsorption stage of dyeing to aid the adsorption by neutralising the negative change on the fibres.

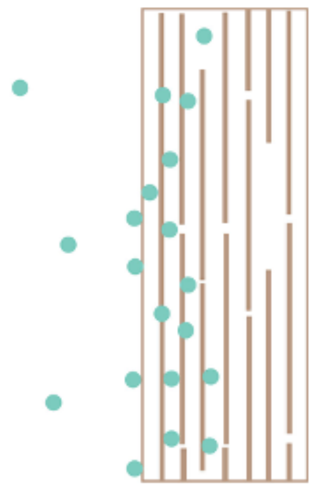
This can be done using:

- the cation of a soluble salt
- acid to control the pH of the fibre and dyebath
- some commercial products.

PENETRATION

Penetration is the movement of the dye molecules through the surface into the fibre.

- Most fibre have a 'skin' of hard or more crystalline material.
- The individual dye molecules migrate through areas of low crystallinity or 'pores' in the surface material.
- Some dyeing auxiliaries are used swell the surface material creating more gaps through which the dye molecule can pass.



27 - Module 1: The dyeing of wool

EXPLAIN THAT most fibres have a 'skin' of more crystalline or oriented polymeric material through which the dye molecules must enter the fibre. This process is called penetration.

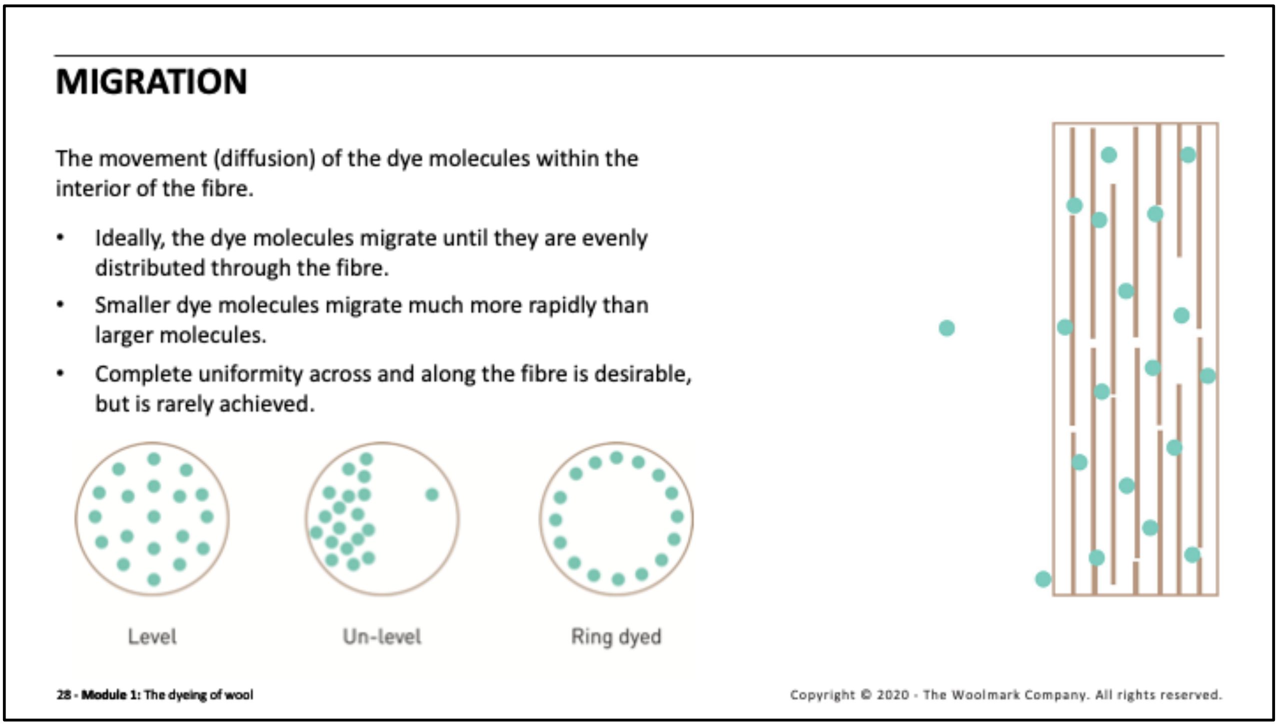
NOTE THAT the process of adsorption onto, and penetration through, the surface of the fibre are together sometimes called 'adsorption'.

ASK *participants why it matters if the dye is concentrated near the surface of the fibre.*

ACKNOWLEDGE *responses and if necessary reinforce that 'ring dyeing' is a dyeing fault caused when dyes do not diffuse or migrate uniformly throughout the fibre. If the dye migrates poorly and has high affinity it can 'fix' on the first available dye site and remain near the fibre surface, resisting further dye diffusion. This means the outer layers of the fibre contain most of the dye and the inner layers have little dye, giving a 'ring-like' appearance to the fibre cross-section.*

EMPHASISE THAT *this fault can lead to poor wash fastness unless the dyes are strongly attached and poor wet and dry rubbing fastness of dyed fabric.*

EXPLAIN THAT penetration is aided by the presence of holes or pores in the surface of the fibre. If there are many dye sites within the fibre, these draw dye molecules away from the surface and into the interior of the fibre. This ensures a suitable concentration gradient of the dye between the outside and inside of the fibre surface and favours penetration by the dye.



POINT OUT that migration of the dye into the interior of the fibre follows the penetration process. During migration the dye moves into the amorphous (non-crystalline) regions inside the fibre and locates a dye site.

EXPLAIN THAT if the dye molecule is large, or the temperature of dyeing is low, migration is slow and bonding can occur at the first available dye site so further migration of the dye is inhibited. This can result in unlevel (uneven) dyeing.

NOTE THAT migration of the dye molecules throughout the fibre is promoted by:
- higher temperatures
- small dye molecules
- a surfeit of dye sites within the fibre.

INDICATE THAT unlevel dyeing occurs when the dye has not migrated evenly throughout the fibre. It is caused by:
- excessively rapid heating
- poor dye dispersion
- insufficient dyeing time
- absence of suitable auxiliaries in the bath
- contamination on the fibre (oil/dirt).

FIXATION

Fixation is the name given to the process by which:

- the dye molecule attaches itself to a site in the fibre so further migration is reduced or eliminated

or

- the dye molecule chemically reacts (forms a covalent link) with a suitable site in the fibre so further migration is prevented

or

- the dye molecule complexes with another species and becomes too big to migrate further

or

- the dye molecule becomes water insoluble (e.g. indigo).

29 - **Module 1:** The dyeing of wool

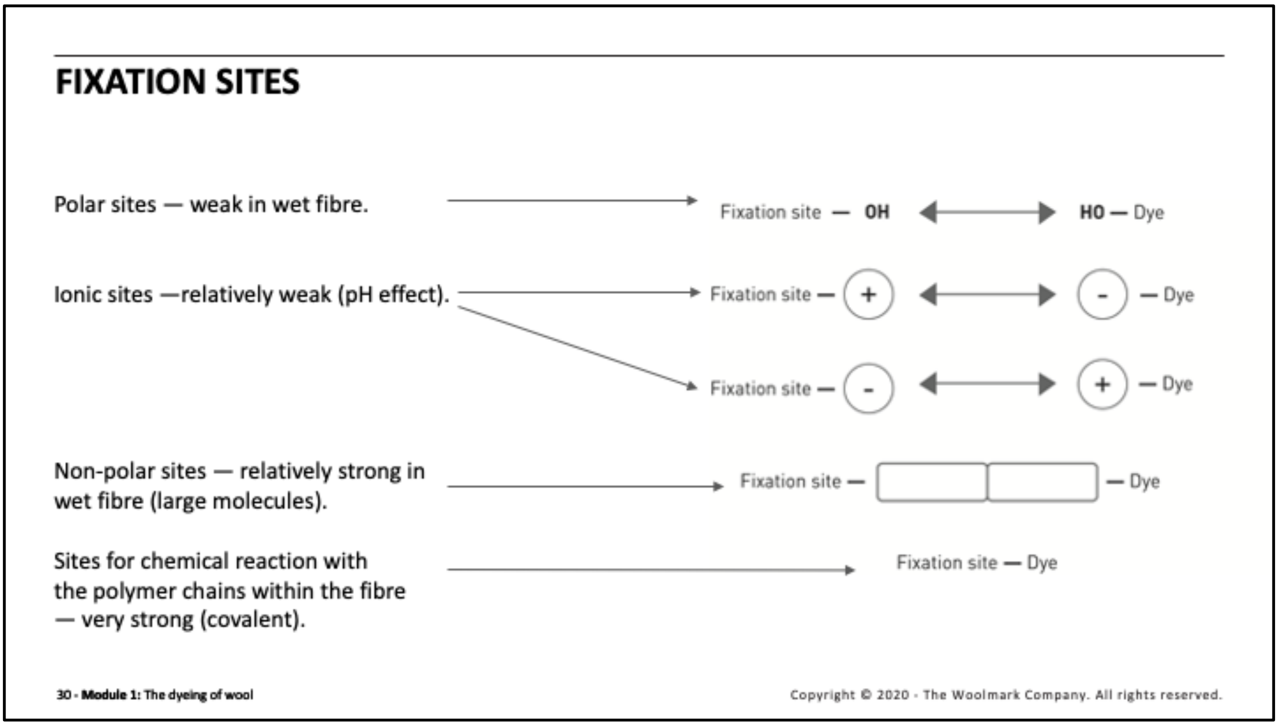
EXPLAIN THAT fixation is the process by which a dye molecule attaches to a dye site (also referred to as a 'fixation' site) within the fibre, or is in some other way immobilised within the fibre.

NOTE THAT fixing implies the formation of a stable association between the dye and the macromolecules of the fibre.

POINT OUT that this can occur when the dye molecule:

- attaches itself to a dye site within the fibre so further migration is reduced or eliminated
- forms a covalent bond with the polymeric chains within the fibre (if the dyestuff is reactive)
- complexes with another compound and becomes too big to migrate further (a process often called mordanting)
- becomes insoluble in water (as is the case with vat or sulphur dyes).

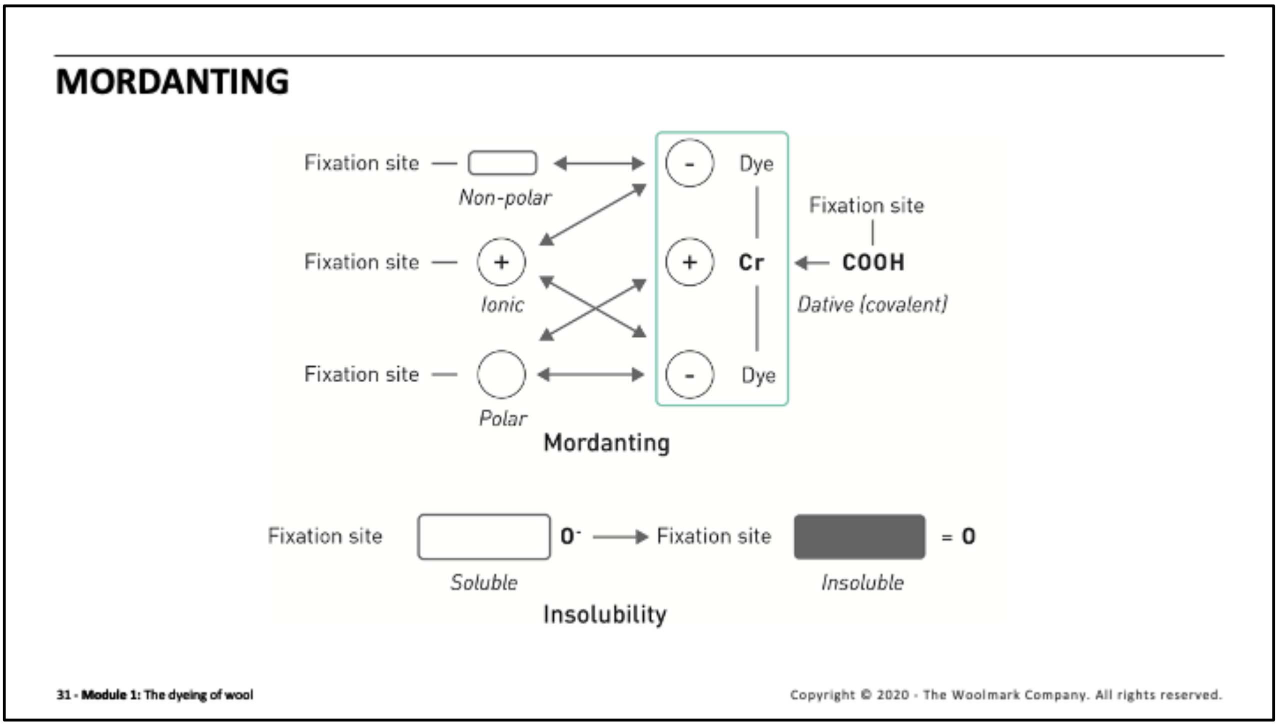
INDICATE THAT fixation is the end of the dyeing process although, in practice for some fibres, subsequent processes may be used to improve fixation.



NOTE THAT within textile fibres, there is a range of sites to which dyes can 'fix'. These sites are indicated on the slide as 'Fixation sites'. The number, types and variety of fixation or dye sites varies with the fibre.

EXPLAIN THERE are four main types of site for fixing dyes on textile fibres:

- **Polar sites** — form links with polar groups on the dyes. These links are weak and can be broken by water or other polar solvents.
- **Ionic sites** —attract dye molecules of the opposite charge. The number of such sites in a fibre often depends on the pH within the fibre.
- **Non-polar sites** — interact with the non-polar sites on the dyestuff. This interaction between non-polar sites occurs only if the fibre is wet, but can be quite strong if the dye molecules are large and relatively hydrophobic.
- **Sites for chemical reaction** — the reactive groups in the dye molecules can form strong and stable covalent bonds with suitable sites on the macromolecules. Such covalent bonds are up to 10 times stronger than non-polar links and four times stronger than ionic interactions.



EXPLAIN THAT as previously discussed, fixation can occur when a complex range of associations form between the dye, the polymer chain and another compound (mordant).

The complex is formed after the dye has entered the fibre (i.e. after penetration).

Mordants are commonly metal salts (chromium, iron, aluminium) although organic compounds can be used.

INDICATE THAT the dye-mordant complex bonds to several types of dye sites in the fibre including polar, ionic and non-polar sites. Metal ions used as mordants may also form dative bonds (a type of covalent bond) with electrophilic sites (i.e. amino, carboxyl) in the fibre.

The size of the mordanted complex is normally much larger than the individual dye molecules.

POINT OUT that fixation can also occur if the dye undergoes a reaction after the dyeing process, which renders it insoluble in water.

EXPLAIN THAT certain classes of dyes (notably vat dyes and sulphur dyes) are water soluble in the presence of alkali and reducing agents. Under these conditions they will dye many natural and man-made fibres.

INDICATE THAT after dyeing, the 'dyestuff' is oxidised and becomes water insoluble and locked into the fibre.

This may involve a change in the colour of the chromophore.

NOTE THAT fixation occurs in 'developed dyes' when the components of the dye react to form the chromophore within the fibre.

TECHNICAL TERMS

Circulation — The movement of the dye liquor

Adsorption — Migration of the dye molecules from the aqueous solution to the surface of the fibre

Penetration — The movement of the dye molecule through the surface of the fibre

Migration — The movement of the dye molecule within the fibre and between fibres.

Fixation — The formation of a stable interaction between the dye molecule and dye sites

Levelness — The evenness of the distribution of the dye through the substrate

Substantivity — Ability of the dye to be absorbed and retained by the fibre

Affinity — A quantitative measure of the attraction between the fibre and the dye

Fastness — The ability to withstand the treatment the fibre undergoes in the processes after dyeing as well as in normal use and aftercare.

32 - Module 1: The dyeing of wool

INDICATE THERE is a range of technical terms used in dyeing with specific meanings, which we will now run through:

Approach/circulation — the movement of the dye liquor through the fibre mass yarn, fabric etc.

Adsorption — movement of the dye molecules from the aqueous solution to the surface of the fibre; also used in the context of adsorption of dye molecules to a dye site within the fibre.

Penetration — movement of the dye molecule through the surface of the fibre.

Migration — movement of the dye molecule within the fibre.

Fixation — the formation of a stable interaction between the dye molecule and dye sites on the macromolecules of the fibre. The term is also used for any process than renders the dye molecule water insoluble within the fibre.

Levelness — the evenness of the distribution of the dye through the substrate.

Substantivity — The ability of the dye to be absorbed from the dyebath and retained by the fibre. The substantivity of a dye for a given fibre is determined by the presence of specific chemical groups on the dye molecule as well as the shape and the molecular weight of the dye molecule.

Affinity — a quantitative measure of the attraction between the fibre and the dye. For simple dyes, substantivity and affinity often depends on the size of the molecule and the number of charged solubilising groups.

Fastness — The ability to withstand the treatment the fibre undergoes in the processes after dyeing as well as in normal use and aftercare without changing colour or bleeding out of or rubbing off the fibres. If the wet fastness of dye is poor it will come out of the fibre during wet processes and stain any adjacent materials. If the light fastness of a dye is poor it will change colour when the article is exposed to light.

NOTE THAT dyers must be able to use these terms like their mother tongue.

MIGRATION, SUBSTANTIVITY AND WET FASTNESS

Small dye molecules:

- have low affinity
- migrate rapidly through the fibre
- offer an even dye across the fibre
- migrate rapidly out of the fibre during laundering (poor wash fastness).

Large dye molecules:

- have high affinity
- migrate slowly through the fibre
- can give poor uniformity of dyeing
- migrate slowly out of the fibre in laundering (good wash fastness).

Dyes with good wet fastness resist migration during laundering

33 - **Module 1: The dyeing of wool**

INDICATE THAT the migration, affinity and wet fastness of dyes and fibres are linked.

EXPLAIN THAT for small molecules with strong solubilising groups, the affinity between the fibre and dye is normally low and depends on ionic attraction between the dye and the fibre.

POINT OUT that large molecules with few solubilising groups are more hydrophobic and are attracted by both ionic forces and the formation of hydrophobic interactions, so have greater affinity.

EXPLAIN THAT small dyes with low affinity can migrate easily within the fibre making level dyeing easier. On the other hand, small dyes also can easily migrate out of the fibre during laundering so wash fastness of small dyes is often low.

NOTE THAT large dyes with high affinity attach more strongly to dye sites and do not migrate easily through the fibre. This raises the problem of unlevel, or uneven, dyeing. On the other hand, large dyes are less likely to migrate out of the fibre in laundering so have better wet fastness than low-affinity small dyes.

MENTION THAT ideally a dye will be small, with relatively low affinity during the early stages of dyeing, but will increase its affinity during fixation.

NOTE THAT this is achieved with reactive dyes, which migrate easily and covalently bond with the macromolecules within the fibre preventing further migration.

MIGRATION, SUBSTANTIVITY AND WET FASTNESS

Mordanting dyes

- Dyes are small during dyeing process.
- Migrate easily — uniform dyeing.
- Made larger by mordanting during fixation.
- Slow migration of dye.
- Good wet fastness.

Reactive dyes

- Dyes are small during dyeing process.
- Migrate easily — uniform dyeing.
- React with fibre polymer chains during fixation.
- Cannot migrate further.
- Good wet fastness.

Soluble–insoluble dyes

- Migrate reasonably well while soluble.
- Migration stops when insoluble.
- Good wet fastness.

34 - Module 1: The dyeing of wool

EXPLAIN THAT for special dye types it is possible to achieve effective migration during dyeing, yet offer a high level of wet fastness after dyeing.

POINT OUT that this is achieved by modifying the dye after the dyeing process is completed and the dyes are fully exhausted onto and migrated into the fibre.

Mordants complex with simple dye molecules to make a bigger molecule with better fastness.

Reactive dyes are generally small dyes, which migrate into the fibre and then react with a nucleophilic group within the fibre to form a covalent bond, which inhibits further migration of the dye.

Soluble–insoluble dyes (vat and sulphur dyes) exhaust and migrate into the fibre while in the soluble form and then oxidise to an insoluble form, which is no longer able to migrate.

MENTION THAT the same rules apply for the acid dyestuffs, but the dye is changed during fixation modifying its characteristics.

DEMONSTRATION: THE PROCESS OF DYEING

NOTE TO FACILITATOR: *Complete the demonstration set up at the start of the lecture.*

Resources required:

- *rinsewater*
- *containers to hold dye liquor*
- *container to hold rinsewater*
- *tongs to extract fabric from dye liquor and rinsewater*

RINSE *the wool and cotton fabric samples.*

ENSURE *all participants can observe the results.*

ASK *participants to note any differences in the colour of the two samples and indicate that the reasons for the differences will become apparent as participants progress through the course.*

SUMMARY — MODULE 1

How textiles are dyed:
- fibre chemistry
- interaction between dyes and fibre types.

Types of fibres (natural, man-made and synthetic) and types of dyes (natural versus synthetic).

Dye types currently used and their features:
- anionic
- cationic
- reactive
- mordant
- vat–sulphur
- disperse.

The physical process and chemistry of dyeing:
- approach
- adsorption
- penetration
- migration
- fixation.

The following concepts were defined and discussed:
- dye sites
- circulation and affinity
- levelness and migration
- substantivity and dye fixation
- wet fastness.

35 - **Module 1:** The dyeing of wool

SUMMARISE THAT this module has introduced the aims of dyeing, the types of fibres subjected to the dyeing process, the dyeing process, the types of dyes used and their action during the dyeing process. You have also been introduced to key terminology used in the dyeing industry.

REMIND participants that to manage a successful and profitable dyeing operation, the dyer must:
- obtain the correct shade
- meet customer requirements for levelness (uniformity of shade)
- meet product requirements in terms of damage and fastness)
- operate within cost limits
- complete the dyeing process on time
- have an environmentally-sustainable operation.

REITERATE THAT the types of fibres to which colour can be imparted through dyeing include:
- natural fibres
- man-made fibres
- synthetic fibres.

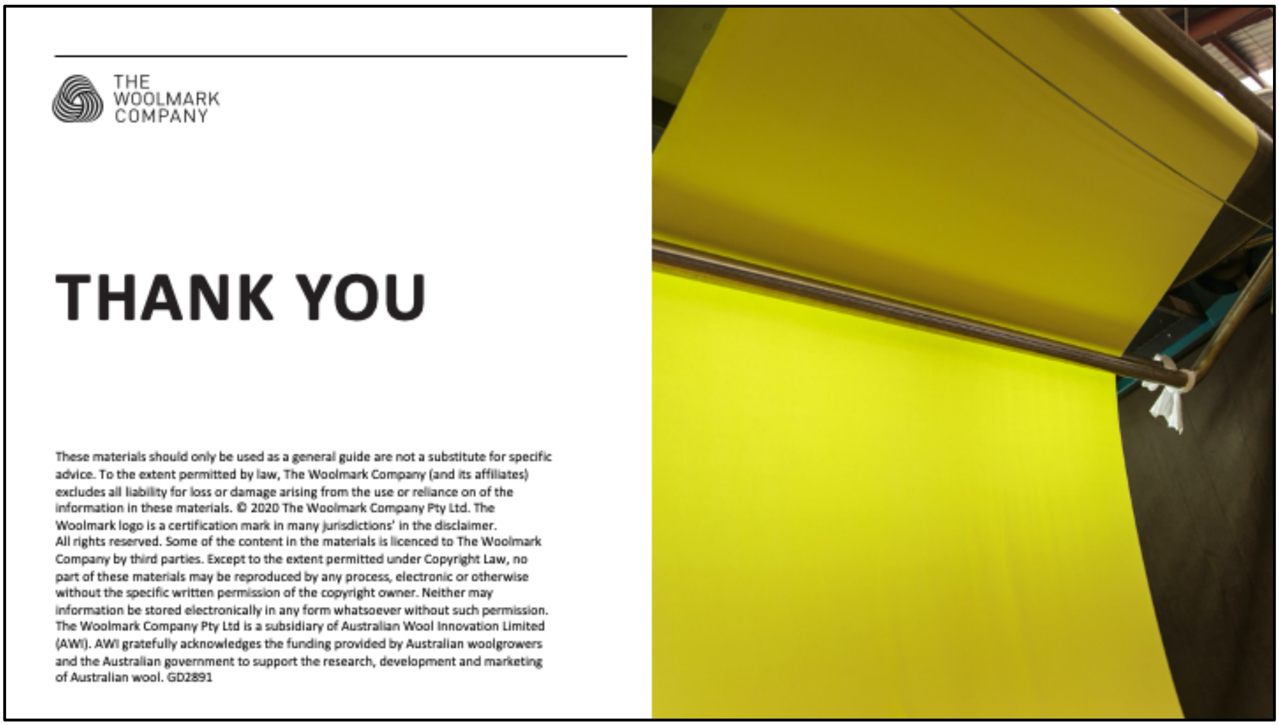
REITERATE THAT the types of dyes currently used to impart colour to fibres, yarns and textiles include:
- anionic dyes
- cationic dyes
- reactive dyes
- mordant dyes
- vat – sulphur dyes
- disperse dyes.

REMIND participants that the following stages of dyeing were outlined:
- approach
- adsorption
- penetration
- migration
- fixation.

REVIEW THE following concepts, which were introduced:
- dye sites
- circulation and affinity
- levelness and migration
- substantivity and dye fixation.
- wet fastness.

***ASK** participants if they have any questions about the content covered in this module.*

***ALLOW** time for questions and discussion before proceeding to the final slide and closing the lecture.*



INFORM participants of the time and location for the next lecture — *Module 2 The dyeing processes in wool* — and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

MODULE 2

THE DYEING PROCESSES IN WOOL

RESOURCES — MODULE 2: THE DYEING PROCESSES IN WOOL

Contained in *The dyeing of wool* Demonstration kit you will find the following resources for use as you deliver **Module 2: The dyeing processes in wool**:

- 3-D wool fibre model

WELCOME participants to Module 2 of the Woolmark Wool Science, Technology and Design Education Program — *The dyeing of wool —The dyeing processes in wool*

INFORM participants that by the end of this module they will be able to:

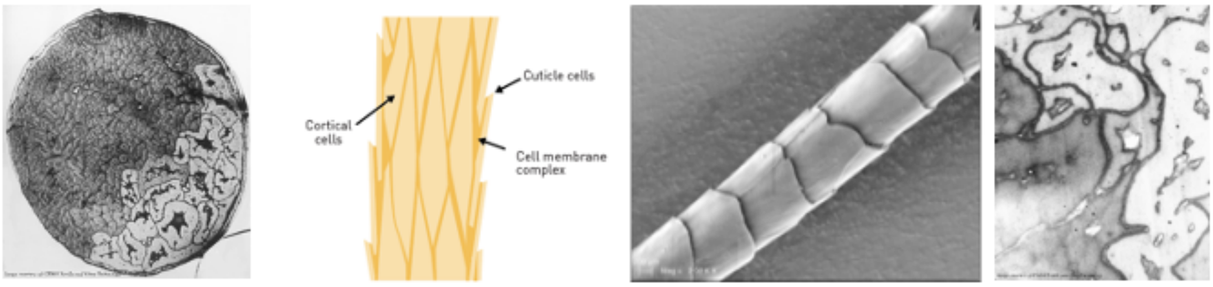
- review the structure of the wool fibre and the chemistry of keratin as they affect the dyeing of the fibre
- explain the relationship between the stages in wool dyeing and its structure and chemistry.

NOTE TO FACILITATOR *if most participants have completed the Wool Science, Technology and Design Education Program course* Wool fibre science *modules on wool fibre structure, physics and chemistry the part of this module on structure, physics and chemistry of the wool fibre can be carried out as a quick review.*

RESOURCES REQUIRED FOR THIS MODULE

- 3-D model of a wool fibre

BRICKS AND MORTAR (AND TILE) MODEL



Fibre cross-section | Image courtesy of CSIRO | Cuticle cells | Cell membrane complex

- A simple model for understanding the impact of fibre structure on dyeing.

2 - **Module 2:** The dyeing processes in wool

EXPLAIN THAT the structure of wool is complex. To understand the impact of fibre structure on dyeing, the simple model illustrated on the slide can be used.

INDICATE THAT this simple structure of wool, developed and used by CSIRO during the 1980s, is called the 'bricks and mortar' model (sometimes the bricks, mortar and tile model).

NOTE THAT for the purpose of dyeing, this model contains all the required information.

POINT OUT that the model (which appears as a longitudinal cross-section of a wool fibre) has three components:

- the spindle-shaped cortical cells (the bricks)
- the cell membrane complex, which glues together the cortical cells (the mortar)
- cuticle cells or scales (the tiles) on the surface of the fibre.

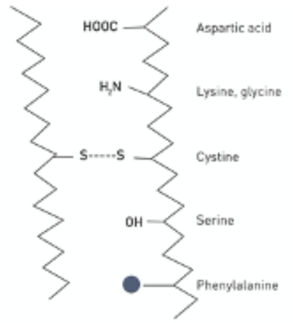
HAND OUT *the 3-D model of a wool fibre.*

ENSURE *all participants can identify the three components mentioned above.*

CHEMICAL COMPOSITION OF THE WOOL FIBRE

- Wool proteins are complex co-polymers.
- Unlike synthetic fibres, the wool fibre is not chemically homogeneous.
- Different structural components have different chemical composition.

Wool proteins make up 97% of the wool fibre and include:
- 170 different proteins and 18 amino acids
  - keratinous proteins (82%) having sulphur crosslinks, which are chemically resistant
  - non-keratinous proteins (15%), which are easily damaged
- lipid material (2–3%)
  - waxy substances
  - important in finishing and use.



Some of the side groups on protein molecules

3 - **Module 2:** The dyeing processes in wool

POINT OUT that as discussed in earlier courses of *Wool Science, Technology and Design Education Program*, wool proteins are complex co-polymers of amino acids.

EXPLAIN THAT unlike synthetic fibres, the wool fibre is not chemically homogeneous — different structural components within the wool fibre have different chemical compositions (as outlined on the slide).

NOTE THAT the chemical composition of the wool fibre can vary:
- between fibre types (reflecting genetic differences in the sheep producing the fibre)
- along the individual fibres, reflecting environmental changes (e.g. changes in nutrition) during growth.

INDICATE THAT as outlined by the illustration on the slide, the amide (peptide) bonds in the polymer chain are polar in nature and can interact with polar groups in other adjacent polymer chains and with adsorbed water molecules.

MENTION THAT some of the key amino acids integral to the dyeing process include: cysteine, cystine, serine, threonine, aspartic and glutamic acid, lysine, histidine, arginine and phenylalanine.

EXPLAIN THAT cysteine has a sulphur side group, which tends to form covalent disulphide bonds between macromolecular chains with other cysteine side groups.

The amino acid in which the sulphur groups of two cysteine residues are joined to form a disulphide bond is called cystine.

Serine and threonine have hydroxyl (–OH) side groups. Hydroxyl groups are polar and can bond to other polar molecules, such as water.

NOTE: All of the amino acids with polar side groups are hydrophilic (water-loving) and can act as sites for association with adsorbed water (and polar dyes).

POINT OUT that aspartic and glutamic acids have a carboxyl side chain, which can ionise at high pH to form a negatively-charged dye site in the fibre.

Lysine, histidine and arginine have amino side groups, which can ionise at low pH to form positively-charged ammonium groups within the fibre, which act as dye sites.

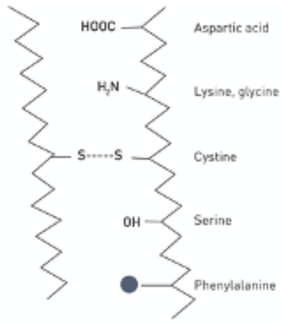
Phenylalanine has an aromatic ring side group which is non-polar. There are also other amino acids in wool with non-polar side groups.

CHEMICAL COMPOSITION OF THE WOOL FIBRE (CONTINUED)

- Wool proteins are complex co-polymers.
- Unlike synthetic fibres, the wool fibre is not chemically homogeneous.
- Different structural components have different chemical composition.

Wool proteins make up 97% of the wool fibre and include:

- 170 different proteins and 18 amino acids
    - keratinous proteins (82%) having sulphur crosslinks, which are chemically resistant
    - non-keratinous proteins (15%), which are easily damaged
- lipid material (2–3%)
    - waxy substances
    - important in finishing and use.



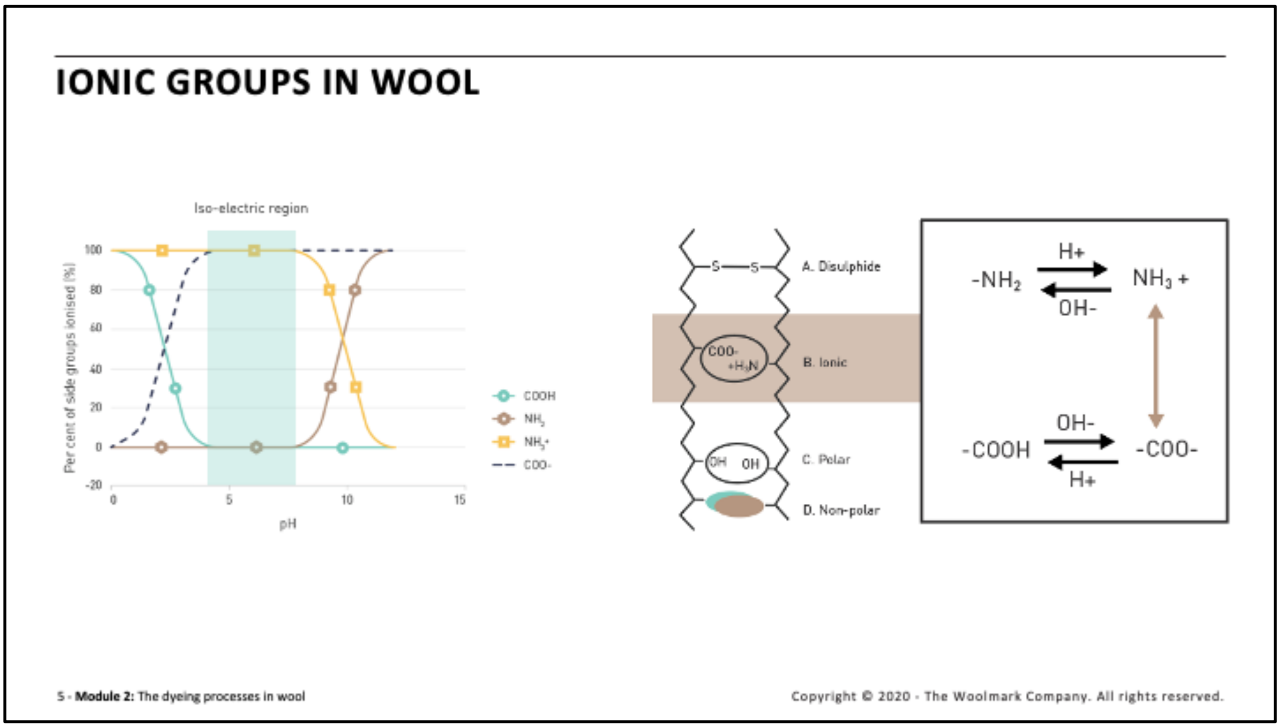
Some of the side groups on protein molecules

4 - **Module 2:** The dyeing processes in wool

EXPLAIN THAT while most of the proteins in wool are keratinous (have cystine or disulphide bond crosslinks), non-keratinous proteins, which are not cross-linked, are a small but important part of the fibre.

INDICATE THAT they are found in several parts of the fibre including the cell membrane complex (CMC) which, as will be described later, are an important pathway for the migration of the dyes within the fibre. Disruption of the CMC will affect the dyeing process.

NOTE THAT in contrast to keratinous proteins, the non-keratinous proteins are more easily damaged.



POINT OUT that the 'ionic groups' in wool, outlined on the slide, are important to the dyeing process because:

- the oppositely-charged groups form links (called salt links) within the fibre between adjacent protein chains (e.g. NH_{3+} and COO_{-})
- these salt links have a stabilising effect on the wool proteins (reducing damage and swelling)
- the charged groups act as dyes sites.

NOTE THAT the concentration of ionic groups in the fibre changes with pH.

EXPLAIN THAT as outlined on the slide, at low pH the concentration of positively charged (e.g. ammonium — NH_3+) groups is high and the number of negatively charged groups (e.g. carboxylate — COO-) is low.

At high pH the concentration of positively charged (e.g. ammonium — NH_3+) groups is low and the number of negatively charged groups (e.g. carboxylate— COO-) is high.

INDICATE THAT when the dyebath pH has a value around the iso-electric region of wool (pH 4.5). the total concentration of charged amino and charged carboxyl groups is at a maximum and the number of salt links is maximised.

NOTE: Depending on the dyes and equipment used, wool dyeing is carried out at a pH in the range pH 2–7.

EXPLAIN THAT because the pKa of the acid side groups (e.g. aspartic acid) is around 3.9 then if the fibre is dyed at pH 2 the groups are not ionised.

Conversely, because the pKa of the basic side groups (e.g. glycine) is around 10, if the fibre is dyed in the normal range (2–7) the groups will be ionised.

STAGES OF WOOL DYEING — APPROACH

Fabric dyeing machine

Regardless of the processing stage at which wool is dyed, the issues and principles remain the same during the approach phase. Effective circulation (of material, dye or both) ensures even exposure of the dye during approach.

- Loose stock dyeing — circulation of dye liquor.
- Top dyeing — circulation of dye liquor.
- Yarn hank dyeing — circulation of dye liquor and yarns.
- Yarn package dyeing — circulation of dye liquor.
- Fabric rope dyeing — circulation of fabric.
- Fabric beam dyeing — circulation of dye liquor.
- Fabric jig dyeing — circulation of fabric.
- Garment dyeing — circulation of garments.

6 - **Module 2:** The dyeing processes in wool

REITERATE THAT wool fibres are dyed in the same five stages as other fibre types — approach, adsorption, penetration, migration and fixation.

Approach

EXPLAIN THAT the dyeing machine circulates the dye liquor and ensures the concentration of dyes in contact with the fibres is even through the fibre mass. Effective circulation ensures equal exposure of all fibres to the dye solution.

NOTE THAT wool can be dyed at various stages through the processing route — from top right through to final garment stage.

During *loose stock and top dyeing* the wool is stationary while the liquor is pumped through the fibre mass.

During *yarn hank dyeing* the dye liquor is circulated in the machine and, in some machines, the yarns are moved as well.

During *yarn package dyeing* the yarn packages remain stationary and the liquor is pumped through them.

During *fabric rope dyeing* a range of options is available: movement of fabric or liquor can occur and, in some machines, both the fabric and the dye liquor are circulated. In some machines the process is aided by jets of dye liquor.

During *fabric beam dyeing* the fabric does not move; the dye liquor is pumped through the fabric.

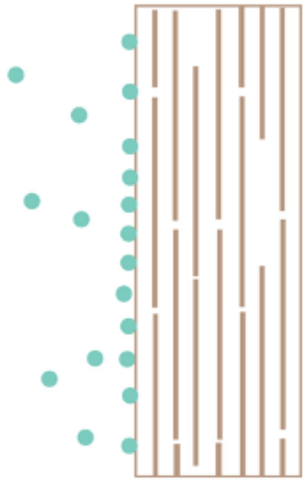
During *fabric jig dyeing* the fabric is circulated through a stationary liquor.

During *garment dyeing* the movement of the garments through the liquor creates the circulation.

STAGES OF WOOL DYEING — ADSORPTION

Adsorption of wool dyes is a function of:

- the concentration gradient from solution to fibre
- the charge on the fibre interior
- the negative surface charge normally found on wool fibres in water
- this charge is normally neutralised through:
  - pH control
  - salts
  - surfactants.



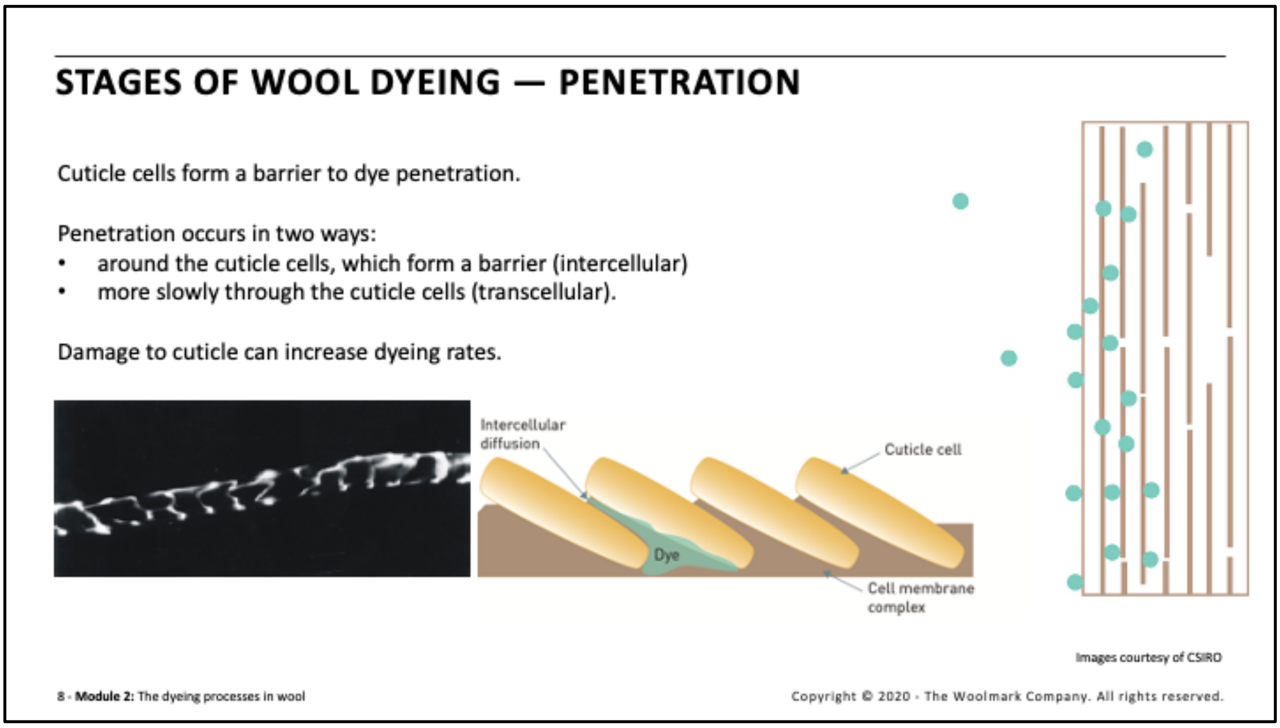
7 - **Module 2:** The dyeing processes in wool

INDICATE THAT wool dyes, especially high-molecular-weight wool dyes have considerable affinity for wool so they can adsorb quickly onto the surface of the fibre.

POINT OUT that the driving force for adsorption is coulombic (involves ionic interactions). This is particularly true at low pH where the surface of the fibre adopts a positive charge due to the number of ammonium groups ($-NH_3+$) groups near the surface of the fibre.

As a result, it can be necessary to slow the adsorption of the dye so it is evenly distributed through the fibre mass

EXPLAIN THAT for dyes with high affinity, the pH of the dyeing solution is maintained above the iso-electric point (pH 4.5) to reduce the rate of adsorption and enhance the even distribution of dye through the fibre mass. Salts and some dyeing auxiliaries (assistants) also contribute to this action.



NOTE THAT during wool dyeing, the upper layers of the surface cuticle cells present a surface barrier dye penetration.

RE-CAPPING — the surface layer of the wool fibre consists of:

- the F-layer
- the epicuticle
- the A-layer, which consist of heavily cross-linked proteins.

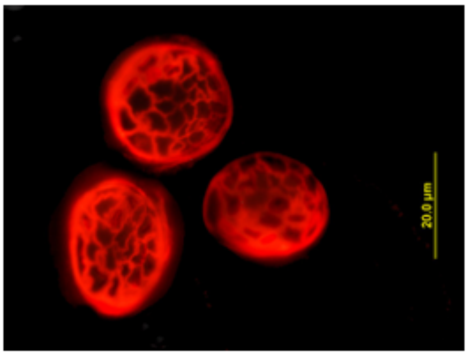
EXPLAIN THAT as shown on the slide, the use of fluorescent dyes indicates that dyes often penetrate the fibres at the junctions between cuticle cells (scales). This is referred to as intercelluar diffusion. The micrograph on the left of the slide shows how dyes concentrate in the regions between the cuticle cells.

INDICATE THAT some penetration also can occur through the cuticle cells (transcellular diffusion). This is inhibited by the F-layer (lipid layer), the epicuticle and the A-layer of the exocuticle, which is not greatly swollen by water. Damage to the cuticle can increase transcellular dye penetration.

STAGES OF WOOL DYEING — MIGRATION

Migration of the dyes through the fibre occurs in two stages:

- through the cell membrane complex (CMC)
- into the keratinous (but non-crystalline) regions of the cortical cells.



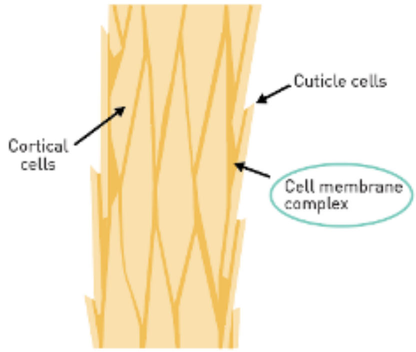


Image courtesy of CSIRO

9 - **Module 2:** The dyeing processes in wool

EXPLAIN THAT the cell membrane complex (CMC) of the wool fibre provides an important pathway for dye diffusion throughout the fibre (migration), particularly during the early stages of the dyeing cycle.

INDICATE THAT the CMC contains keratinous proteins, non-keratinous proteins and lipid material. It has been suggested the lipid material may impede dye migration through the CMC, but the rate of migration of dyes through the CMC is still faster than through the heavily crosslinked cuticle cells.

POINT OUT that following migration through the CMC, the dye then migrates (diffuses) into the keratinised, but non-crystalline, regions of the cortical cells.

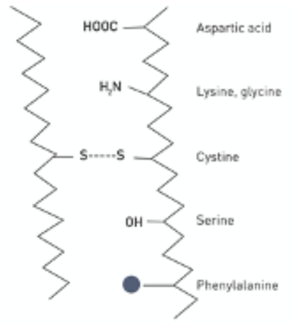
NOTE: It is generally considered that the dye sites within the cortex are contained in matrix material or areas of low crystallinity.

INDICATE THAT dye substantivity is higher in dyes with higher hydrophobic character (reduced hydrophilic character).

STAGES OF WOOL DYEING — FIXATION

Wool has a range of sites to which dye molecules can attach:

- Polar groups — weak, disrupted by water.
- Ionic groups — pH dependent.
- Non-polar groups — hydrophobic interaction.
- Nucleophilic groups
  - reaction with dye
  - complex with mordant.



Some of the side groups on protein molecules

10 - **Module 2:** The dyeing processes in wool

NOTE THAT as previously mentioned, wool has a range of sites to which dye molecules can attach. These sites vary in their affinity for the dye molecules. The groups include

- polar groups
- ionic groups
- non-polar groups
- nucleophilic groups.

Fixation on wool fibres occurs through the formation of both ionic and hydrophobic interactions between the protein chains and the dye molecules.

EXPLAIN THAT dyes linked only by ionic interactions have good levelling properties (a term used to describe dyes that can applied evenly to the substrate without much difficulty) but are susceptible to further migration (poor fastness) if the balance of ionic groups in the fibre changes due to increases in pH (as occurs during laundering pH~9).

POINT OUT that although not initially a driver of the penetration of the dye into the fibre, non-polar groups within the fibre are responsible for the affinity of the dye through hydrophobic interactions.

INDICATE THAT at the end of the dyeing process, most of the dye is held within the keratinous proteins of the fibre, which have greater affinity for the dye than the non-keratinous regions of the cortical cells or the cell membrane complex.

EXPLAIN THAT wool fibres also contain many nucleophilic groups with which reactive dyes can form covalent bonds. As a result, such dyes are widely used where a high level of wash fastness is required.

Specific -wool dyes are mordanted using a chromium salt to improve fastness.

NOTE THAT in sulphonated dyes, the more polar the dyes the lower their substantivity (ability to be held within the fibre):

- tetrasulphonated < trisulphonated < disulphonated < monosulphonated.

TYPES OF WOOL DYES

Acid dyes, which include:
- acid levelling dyes — low affinity
- acid milling dyes (class 1) – medium affinity
- acid milling dyes (class 2) – high affinity
- super milling dyes (class 3) - very high affinity.

Chrome dyes are a mordant dyeing system in which the dyed wool is treated with a chromium salt.

Pre-metallised dyes are anionic dyes in which the metal containing chromophore is pre-formed during the manufacture of the dye.

Reactive dyes are a class of dyes that react (form covalent bonds) with protein molecules.

11 - **Module 2:** The dyeing processes in wool

NOTE THAT there are four groups of synthetic dyes used to dye wool:
- acid dyes
- pre-metallised dyes
- chrome dyes
- reactive dyes

The acid dyes are anionic dyes, which vary in molecular weight and colour range and are widely used in the wool industry. Although they have been replaced by other dye types in many applications, they are used in products requiring good levelling properties as well as those requiring a reasonable level of fastness.

EXPLAIN THAT acid dyes are generally classified into three (or optionally four) groups as shown on the slide. The Society of Dyers and Colourists (SDC) recognises four groups based on the pH of application. The acid milling dyes are also called FAST acid dyes.

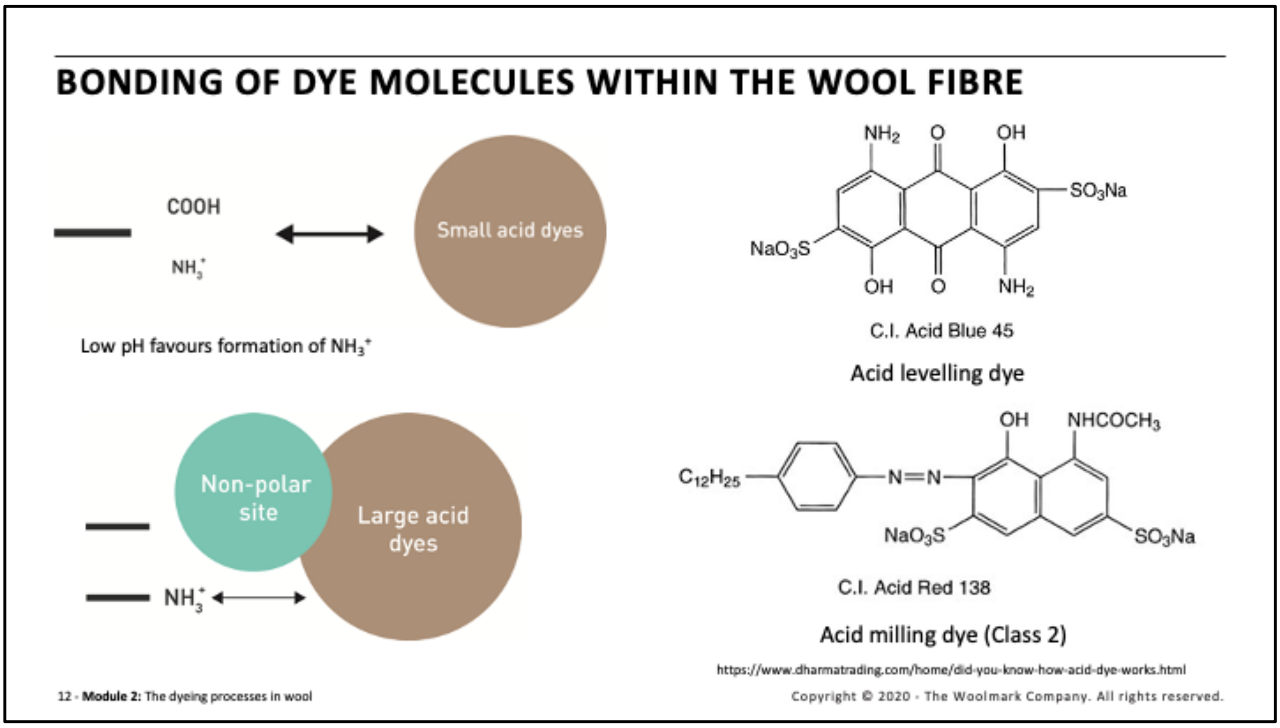
Chrome dyes are a mordanting dyeing system, which relies on the use of chromium salts or complexes as mordants. The chromium complexes with the dye molecules and the protein chains.

The pre-metallised dyes (also called metal complex dyes) are a form of anionic dye, but the chromophore is a metal complex (usually chromium) formed during production of the dyestuff. Pre-metallised dyes were developed to maintain the excellent fastness of chrome mordant dyeing, without the complexities and problems associated with the mordanting process.

INDICATE THAT there are two types of pre-metallised dyes:
- 1:1 pre-metallised dyes — metal ion complexed with one dye molecules.
- 1:2 pre-metallised dyes — metal ion complexed with two dye molecules.

Reactive dyes are anionic dyes with an electrophilic reactive group — often an activated double bond — which can react with nucleophilic sites within the wool fibre to form covalent bonds. The LANASOL range of reactive dyes contains one or two bromo-acrylamide reactive groups.

POINT OUT that in recent years dyestuff companies have started to sell mixed dye systems combining dyes that are applied under similar conditions in a particular commercial range. In practice, acid milling acid and 1:2 pre-metallised dyes can be mixed and sold as a commercial dye range.



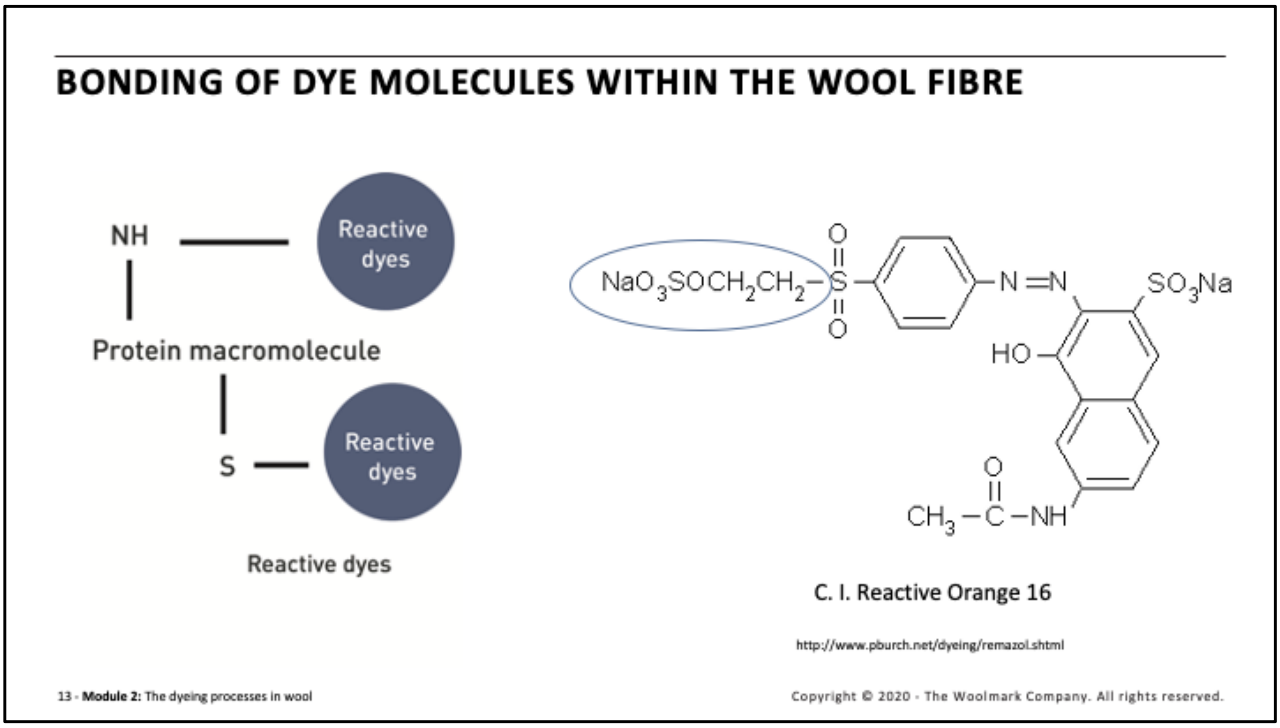
EXPLAIN THAT the nature of bonding between wool proteins and dye molecules varies with the type of dye.

Small acid dyes — The chromophore has a negative charge and these primarily bond with positive sites in the wool fibre. These dyes are applied at low pH to favour the formation of ammonium groups (positively-charged dye sites).

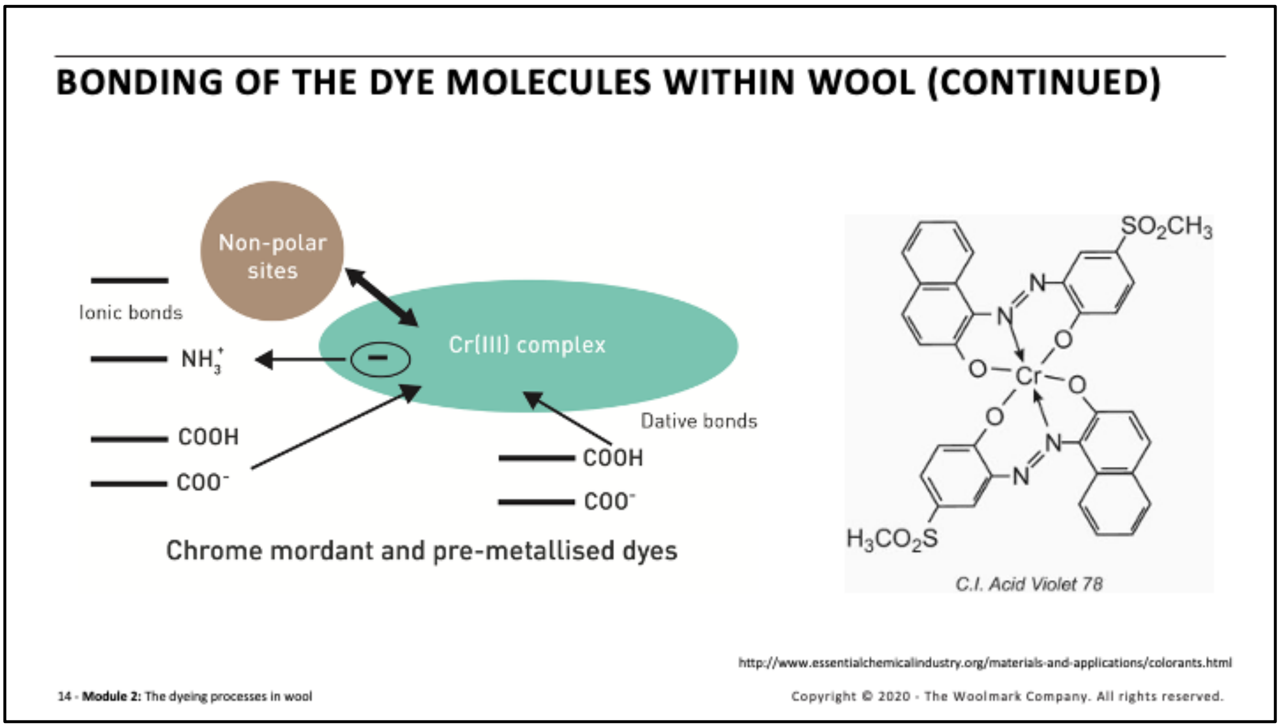
Large acid dyes — These dyes are attracted to positive ammonium sites (NH_3^+) and also bond with non-polar sites in the wool, inhibiting further migration.

INDICATE THAT the dye structures shown on the slide are:

- a typical small acid levelling dye with low affinity — C.I. Acid blue 45
- a typical larger acid milling dye with higher affinity — C.I. Acid Red 138.



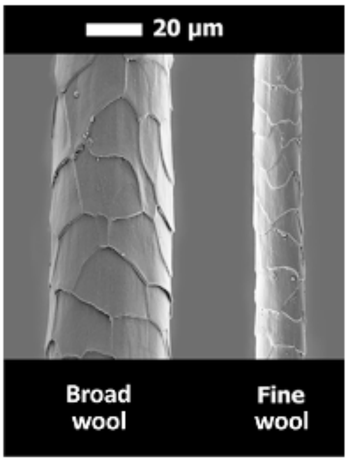
EXPLAIN THAT reactive dyes, such as C. I. Reactive Orange 16 shown on the slide, form covalent bonds with amino groups and thiol side chains (NH_2 and SH) on the protein macromolecule, preventing their subsequent migration and ensuring a high level of wet fastness.



INDICATE THAT the chrome mordant and pre-metallised dyes bond with the fibre through a number of mechanisms including:

- ionic attraction to ammonium groups
- dative bonds between the chromium ions and nucleophilic groups on the protein chains
- interaction with non-polar groups on the protein chains.

EFFECT OF FIBRE DIAMETER



Fine wool fibres dye to a lighter shade than broader wool fibres.

The effect is optical rather an indicator of exhaustion of the dye onto the fibre.

More dye must be used to achieve specified colours in fine wool.

15 - **Module 2:** The dyeing processes in wool

NOTE THAT the depth of colour achieved in fine wool fibres with a given concentration of dye is lighter than that obtained with broad wool fibres.

EXPLAIN THAT the greater surface area of the finer fibres leads to more scattering and reflection of incident light, which causes the material to appear lighter. Lower fibre diameter wools generally require a higher concentration of dye to achieve a specified colour.

INDICATE THAT the magnitude of the effect of fibre diameter on shade depends on the depth of the shade required. The required increase in dye concentration can be determined by carrying out quality control checks during the dyeing process.

EXPLAIN THAT for relatively small changes in fibre diameter there is a simple rule that can be empirically applied —"Change the dye concentration proportionally to the surface area of the fibre".

FOR EXAMPLE, a dye recipe for 21µm wool can be adjusted for a 19µm fibre as follows:

$$\frac{(\text{Diameter broad})^2}{(\text{Diameter fine})^2}$$

$$(21/2)^2/(19/2)^2 = 212/192 = 1.222$$

The 19µm fibre needs about 20% more dye to achieve the same depth of colour as the 21µm fibre.

ROOTS AND TIPS

The tips of wool fibres often dye darker than roots of the fibre due to the effects of:

- weathering
- UV damage.

Some dyes cover the difference well; others do not.

16 - **Module 2:** The dyeing processes in wool

NOTE THAT during the 8–12months the wool fibre is on the sheep's back it is exposed to the weather and particularly the effects of UV-exposure (i.e. sunlight).

EXPLAIN THAT the tip of the wool, being on the outside of the fleece, receives a higher level of exposure and mechanical damage than the root of the fibre, against the animal's skin. This can be seen in scanning electron micrographs of the fibre.

INDICATE THAT this exposure to the elements and subsequent damage can create dyeing differences between the tip and the rest of the fibre. This is called 'tippy' dyeing.

MENTION THAT the potential of wool fibres to dye in a tippy manner can be assessed by dyeing a sample with:

- C.I. Reactive Yellow 39 1.0%
- C.I. Acid Blue 185 1.0%.

The testing process is carried out at pH 5.0.

EFFECT OF PRE-TREATMENTS ON THE DYEING OUTCOME

A number of pre-treatments used during wool processing modify the dyeing result:

- raw wool scouring
- carbonising
- felt-resist treatments (top, yarn, fabric or garment stages)
- yarn steaming
- fabric setting
  - fabric crabbing (end-to-end effects)
  - uneven chemical setting
- garment processing.

17 - **Module 2:** The dyeing processes in wool

NOTE THAT treatments conducted on yarn and fabric before dyeing can impact on the dyeing outcome.

Raw wool scouring conditions can affect dye uptake. Shade differences can occur if dyeing lots are made up of different scour batches.

Carbonising damages the fibres and modifies the pH of the fibre, affecting dye uptake.

Felt-resist processes on top, yarn, fabric or garment modify the dyeing behaviour of the wool fibres. Blends of treated and untreated wool should always be made after dyeing.

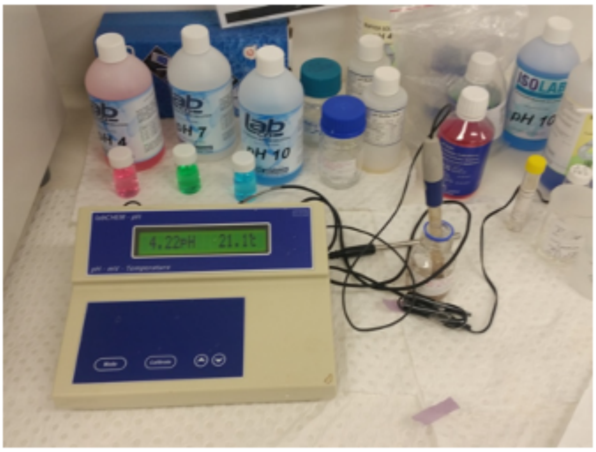
EXPLAIN THAT yarn steaming affects dye affinity. Cone-to-cone shade differences can occur if dye lots are made up of different steaming batches. Condensation or non-uniformity of steaming can lead to unlevelness in yarn or piece dyeing.

INDICATE THAT pre-setting operations on fabric will modify the dye uptake of wool fibre, so that uneven setting (while not necessarily visible in the product) will result in uneven dyeing (which is visible).

POINT OUT that it is vital to check the dyeing properties and uniformity of each lot of material before dyeing in bulk.

MENTION THAT wet garment processing is described fully in the unit of the *Woolmark Wool Science, Technology and Design Education Program* course, *Wool garment finishing.* The process involves scouring and milling of garments and often includes felt-resist treatment. All these processes can affect dye uptake.

THE IMPACT OF FIBRE pH ON THE DYEING PROCESS



The pH of wool substrates for dyeing can vary:
- the raw wool was scoured (neutral or alkaline)
- yarn, fabric or garment were scoured
- the nature of any milling additives
- the nature of any felt-resist process
- unevenness and batch differences can occur particularly when applying fast dyes.

Measurement of pH of wool:
- weigh 2g of wool and place in a conical flask with 100ml deionised water
- shake for 1 hr. and measure the pH with a calibrated pH meter.

18 - **Module 2:** The dyeing processes in wool

INDICATE THAT the pH of wool substrates for dyeing can vary, according to:
- the raw wool scouring conditions (neutral or alkaline)
- whether the wool was scoured in yarn, fabric or garment form.
- the nature of any milling
- the nature of any felt-resist treatments.

NOTE THAT unevenness and batch differences can occur as a result of differences in substrate pH, particularly when applying fast dyes, such as 1:2 metal complex, milling and reactive dyes.

EXPLAIN THAT the main requirement for successful and consistent dyeing outcomes is consistency of pH throughout the dyeing process. The actual pH of each batch must checked before any dyeing is undertaken.

MENTION THAT checking the pH of an aqueous extract of the wool substrate should form part of the standard tests carried out before dyeing new lots of wool.
The following pH test is based on IWTO-2-96 and is conducted as follows:
- Weigh 2g of wool and place in a conical flask with 100ml deionised water.
- Shake for one hour and measure the pH with a calibrated pH meter.

TESTING THE SUBSTRATE — PURE NEW WOOL

Recommended methods include:
- ISO 3071:2005 Determination of pH of aqueous extract
- AATCC TM159 Transfer of Acid and Premetallised Acid Dyes on Nylon – can be used for wool.

Commercial tolerances for differences in shade depend on:
- article (is unevenness acceptable)
- customer
- colour.

PURE NEW WOOL®

19 - **Module 2:** The dyeing processes in wool

INDICATE THAT wool is a natural fibre and it is subject to variability from lot to lot. Differences in dyeing properties can lead to shade differences that exceed commercial colour tolerances.

Differences in substrate colour can be taken into account by most recipe prediction software systems and simply require the undyed material, prepared for dyeing, to be measured on a spectrophotometer. Most modern software systems will automatically adjust recipes from a standard substrate to ensure consistency of dyed shades on the new material.

Determination of pH of aqueous extract . The recommended method is ISO 3071:2005.

EXPLAIN THAT to check the dyeing properties of any wool substrate it should first be scoured if necessary, using a standard process. One or more samples should then be dyed to standard recipes, preferably trichromatic shades, and any differences from the standard substrate measured. These can then be taken into account in recipes on the new substrate.

NOTE THAT many recipe prediction systems will carry out this function automatically.

POINT OUT that the differences in colour and levelness that will be tolerated in commercial practice depend on , the customers requirements, the products and the shade to which it is dyed.

TESTING BLENDED SUBSTRATES

WOOL RICH BLEND

WOOL BLEND PERFORMANCE

20 - **Module 2:** The dyeing processes in wool

MENTION THAT testing to determine the dyeing properties of fibre blends adds another layer of complexity to the process.

INDICATE THAT tests to determine the dyeing properties of synthetic fibres (normally dye affinity and saturation values) differ according to the fibre type.

NOTE THAT when testing to determine the dyeing properties of a wool–synthetic blend cross staining of dyes on each fibre type must be taken into account.

EXPLAIN THAT chemical treatments, such as bleaching and felt resist processes, also affect the dyeing of wool in blends. Such processes normally have only minor effects on the degree of wool staining with disperse and basic dyes, used respectively for polyester and acrylic blends. However, they will significantly increase wool staining with direct and reactive used for dyeing blends with cellulosic fibres.

SUMMARY — MODULE 2

Wool fibres have complex structure with regions that differ structurally and chemically, which affect the dyeing process.

Dyeing of wool occurs in a series of overlapping processes as the dye molecules

- **Approach** the fibre as dye liquor circulates
- **Adsorb** onto the fibre surface concentrating at gaps between cuticle cells
- **Penetrate** the fibre primarily around the cuticle cells
- **Migrate** through the fibre via the cell membrane complex then diffuse into the keratinous regions of the cortical cells
- **Fix** to dye sites within the fibre by forming:
  - primarily ionic bonds
  - a mixture of ionic and hydrophobic interactions
  - covalent bonds
  - mordanting with a metal ion to form ionic and dative bonds as well as hydrophobic interactions with the protein.

21 - **Module 2:** The dyeing processes in wool

REMIND participants that wool fibres have complex structure with regions that differ structurally and chemically.

SUMMARISE this module by explaining that dyeing of the fibre occurs in a series of overlapping processes as the dye molecules

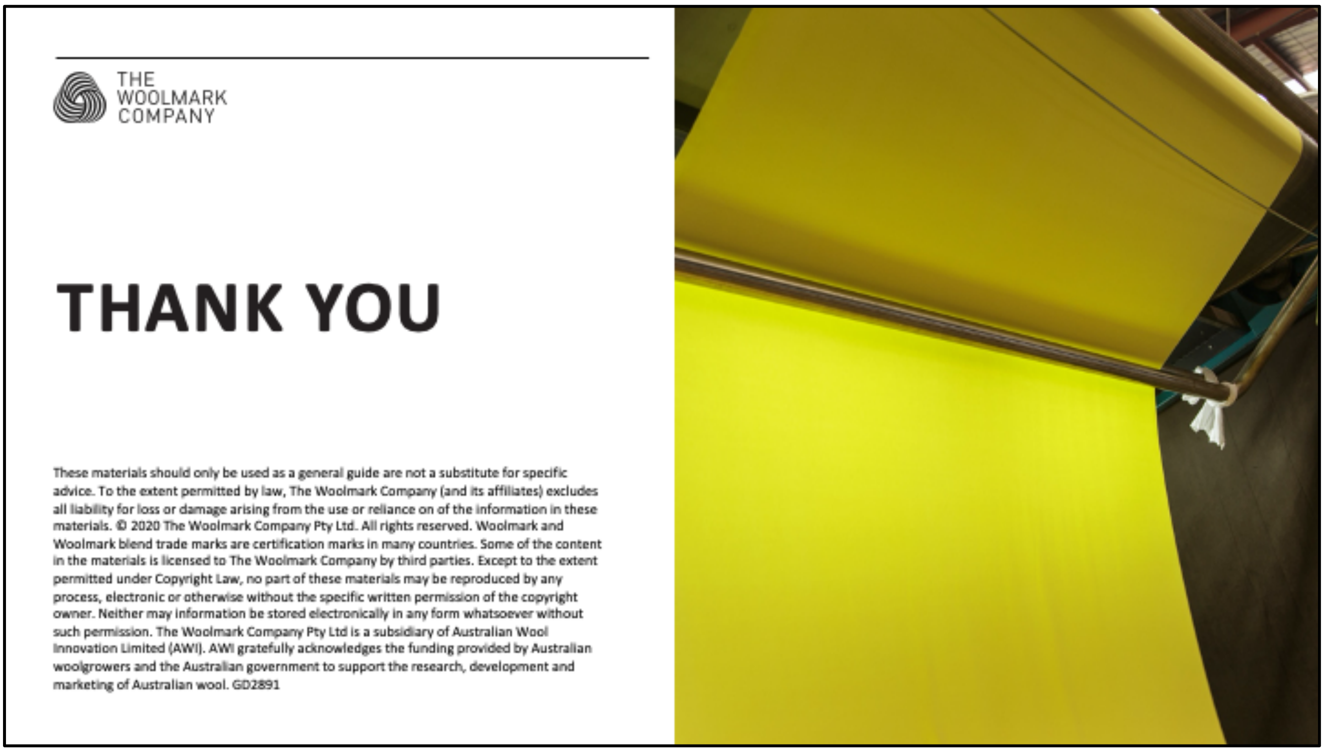
- approach and enter the fibre primarily around the cuticle cells
- migrate through the fibre via the cell membrane complex (CMC)
- diffuse from the non-keratinous regions into the into the keratinous regions of the cortical cells. (Diffusion is driven by the availability of cationic sites within the fibre. This depends on fibre pH)
- fix to dye sites within the fibre. Fixation often involves the formation of hydrophobic interactions between the protein chains within the fibre and the dye, which confer substantively. Fixation can also involve chemical reactions between protein and the dye, forming covalent or dative bonds

REITERATE THAT quality and type, fibre diameter and pre-treatment all influence the uptake and shade depth on wool.

REVIEW the fact that if the wool has been treated by a chemical process (e.g. scouring or felt-resist-process) its dye affinity can be appreciably changed.

***ASK** participants if they have any questions about the content covered in this module.*

***ALLOW** time for questions and discussion before proceeding to the final slide and closing the lecture.*



INFORM participants of the time and location for the next lecture — *Module 3 Preparing wool for dyeing* — and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

MODULE 3

PREPARING WOOL FOR DYEING

RESOURCES — MODULE 3: PREPARING WOOL FOR DYEING

Contained in *The dyeing of wool* Demonstration kit you will find the following resources for use as you deliver **Module 3: Preparing wool for dyeing**:

- samples of wool in natural and bleached state
- samples of pigmented wool in natural and bleached state

WELCOME participants to Module 3 of the Woolmark Wool Science, Technology and Design Education Program — *The dyeing of wool — Preparing wool for dyeing*

INDICATE THAT the preparation of wool for dyeing is almost as important as the dyeing process itself. It is commonly said that "well prepared is half dyed".

EXPLAIN THAT all sources of potential unevenness, due to differences in dye affinity between the fibres or sections of the load, must be removed where possible, or at least reduced to an acceptable level.

NOTE THAT there are differences in the way wool is prepared for dyeing depending on whether it is to be dyed in the form of:

- loose stock
- top
- yarn
- fabric
- garment

EXPLAIN THAT this module will outline:

- the methods used to prepare wool for dyeing
- the particular issues that apply to bright colours (particularly bright blues)
- the bleaching of wool (reason for bleaching and the methods used).

INFORM participants that by the end of this module they will be able to describe:

- the techniques used to prepare wool in its various forms for dyeing
- the techniques used to ensure water used in dyeing is of suitable quality
- the preparation of chemically-treated wool
- bleaching processes used to prepare wool for dyeing to pastel shades
- conditions for balancing colour and fibre damage when bleaching
- the bleaching of pigmented wool.

RESOURCES REQUIRED FOR THIS MODULE

- *samples of wool in natural and bleached state*
- *samples of pigmented wool in natural and bleached state*

TO ENSURE SUCCESSFUL DYEING

Consistent substrate:
- history/preparation
- fibre diameter
- chemical pre-treatment
- fibre pH
- blend composition.

Consistent dyestuff application:
- concentration
- moisture content
- weighing.

Consistent process control:
- water quality
- time and temperature profile
- liquor-to-goods ratio
- dyebath pH
- liquor flow.

2 - **Module 3:** Preparing wool for dyeing

EXPLAIN THAT there are three requirements for achieving a good (even) dyeing of wool:
- a consistent substrate (i.e. fibre, yarn, fabric), with no gross differences in affinity between fibres or sections of the dye batch.
- even application of the dye to the load
- control of the process so the exhaustion of the dye occurs in an appropriate manner.

NOTE THAT the history and preparation of the substrate is key to a consistent substrate.
- All oils and waxes should be removed before dyeing.
- The pH of the wool should be consistent throughout the batch.

POINT OUT that where a broad range of fibre diameters exists in the blend, the preceding blending process must be adequate so any differences in colour resulting from differences in fibre diameter are minimal and will not effect the outcome of the dyeing process.

Likewise with chemical treatments, which are known to affect dye uptake, especially those associated with the felt-resist treatment of wool.

EXPLAIN THAT the setting of wool also affects dye uptake, and differences in setting can result in an unlevel dyeing. If wool yarn gets wet in sections during yarn steaming, this can show up when the yarn is subsequently dyed.

MENTION THAT finally, blends of wool with other fibre types must be even so differences in colour do not show up in the final product

---

ASK *participants which form of setting would be expected to have the greatest effect on dye uptake — cohesive or permanent set?*

ALLOW *participants sufficient time to respond.*

ACKNOWLEDGE *responses and if necessary reiterate that permanent setting would have the greatest effect on dye uptake.*

WATER USED FOR DYEING

PARAMETER	PROCESS WATER	BOILER WATER
Colour	Hazen No. Clear 2–5	
pH value	7.0 –7.5	7.0 – 8.0
Total hardness	10–25 ppm	Below 1.0 ppm
Alkalinity to methyl orange	35–65 ppm	
Iron	0.02–0.10 ppm	Below 0.01 ppm
Manganese	0.03 ppm	Below 0.01 ppm
Total dissolved solids	65–150 ppm	100 ppm
Suspended solids	Nil	

Water quality is critical when dyeing and finishing textiles.

It is also the precursor for steam, which is widely used to heat the water in many dyeing and finishing processes.

Water of the correct purity is important for successful dyeing.

3 - **Module 3:** Preparing wool for dyeing

NOTE THAT the use of suitably-prepared water is critical for effective dyeing.

EXPLAIN THAT the importance of individual contaminants in water will depend on the processes being carried out, but the data shown on the slide above covers most applications.

INDICATE THAT solid particles, or products that can generate solids, during processing must be avoided completely in any process as these solids will filter onto the fibres.

POINT OUT that hardness, from calcium or magnesium salts, can affect scouring efficiency and lead to deposits on the material being processed.

Heavy metal contaminants, including copper and other metals may be encountered locally.

EXPLAIN THAT transition metals can cause particular problems in mordant dyeing, because mordant dyes can complex with metal ions other than those used in the mordant to produce different shades.

SOURCES OF WATER

The site of many wool-processing centres is determined by the availability of suitable water.

Local authority
- Depends on purification techniques used.

Bores and springs
- Hardness depends on region.

Tanks
- Collected rainwater is soft.

River
- Hardness depends on region and extent of local industry.

Re-cycled water
- Quality depends on source, previous use and on purification techniques used.

4 - **Module 3:** Preparing wool for dyeing

NOTE THAT the need to test and treat processing water will depend on its source.

EXPLAIN THAT many companies now take their water from a national grid system, so the quality can vary within limits set by the supplier or local authority.

Others take their water directly from surface or underground supplies, which can vary according to the season and local environment (e.g. soil type and vegetation).

INDICATE THAT all water must be tested and treated accordingly before use. Common methods for treating water are discussed on the next slide.

PREPARATION OF WATER FOR DYEING

Water preparation depends on available equipment

The method used to prepare water for dyeing depends on:

- the water source
- the base quality of the water
- available equipment.

Common methods used to treat processing water include:

- filtration
- addition of lime and soda
- chelating agents
- ion exchange resins
- reverse osmosis.

5 - **Module 3:** Preparing wool for dyeing

EXPLAIN THAT the method used to improve the quality of water used during the dyeing process depends on:

- the source of the water
- its existing quality
- the equipment available to treat it.

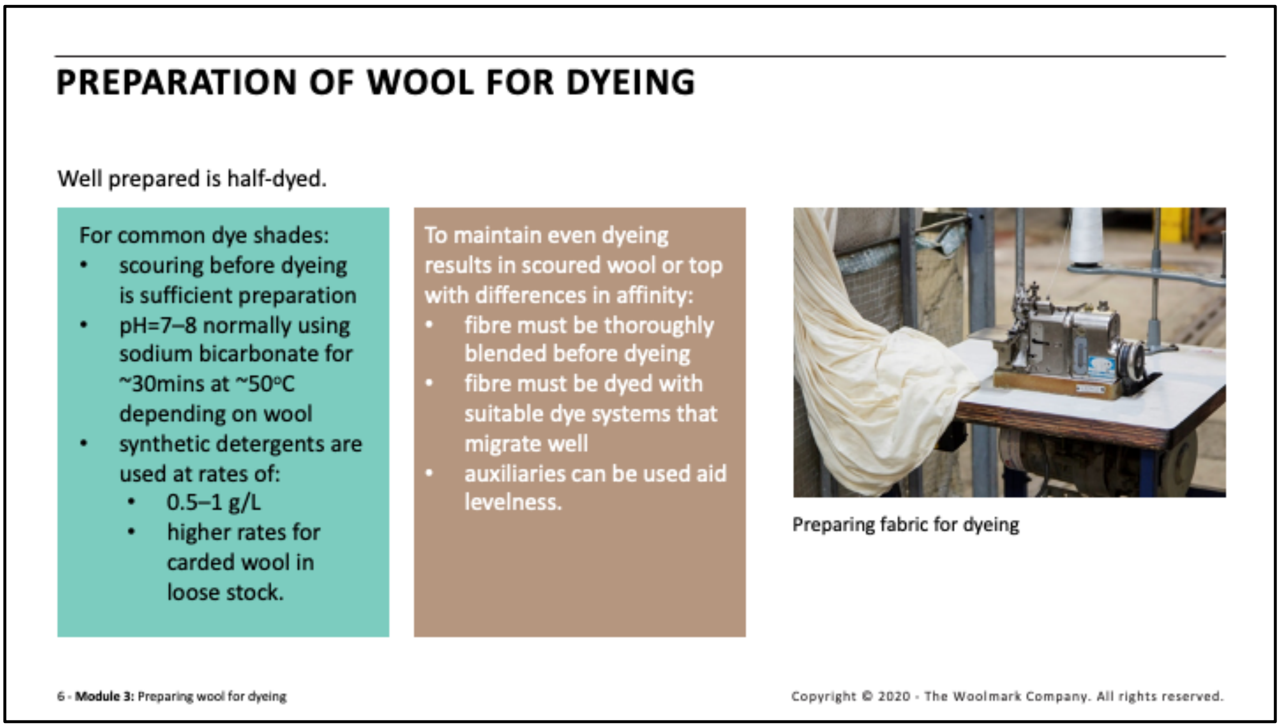
Filtration
Filtration removes suspended solids contained in the source water. All ground or re-cycled water should be filtered to remove any suspended solids.

Addition of lime and soda
This technology dates back to the early 19th century (1841). It is effective at reducing both hardness and total dissolved solids, precipitates calcium and magnesium salts and reduces total solids.

Chelating agents
Chelating agents (such as ethylenediaminetetraacetic acid — EDTA) can be used to complex the calcium and magnesium ions in the source water and are commonly used in domestic laundries. However, they can interfere with metal-containing dyestuffs used on wool. The formerly popular product called EDTA is now banned because of its environmental impact.

Ion exchange resins
These resins capture calcium and magnesium ions and replace them with sodium ions so are widely used to 'condition' water.

Reverse osmosis
A semi-permeable membrane can be used to remove dissolved solids through the process of reverse osmosis. This is a more expensive process than the previously mentioned treatments and is used where a reduction in total dissolved solids is also required.



INDICATE THAT in practical terms, scouring the load (i.e. top, yarn and piece goods, garments or garment pieces) immediately before dyeing is normally sufficient to prepare the wool for dyeing.

EXPLAIN THAT scouring is required because:

- Wool top contains lubricating oils that can affect dyeing.
- Wool yarns, especially those used for woollen products, contain spinning oils, which are used to facilitate the spinning process. These oleine-based oils are emulsified using anionic or non-ionic surface-active agents.
- Woven and knitted fabric can contain waxes used to 'dress' the yarns before the fabric forming process. Modern lubricants and spinning, weaving and knitting aids are formulated to ensure easy removal. They are normally water soluble or miscible.

NOTE THAT in most cases (and for common colour shades) scouring at 50-60ºC for 15–30 minutes, at a pH of 7–8 using sodium bicarbonate, before dyeing is adequate. Synthetic detergents are commonly used at rates of about 0.5–1.0g/L (rates may be higher for carded wool in loose stock).

POINT OUT that to achieve an even (level) dyeing results in scoured wool or top where there may be differences in affinity throughout the load:

- fibre must be thoroughly blended before dyeing
- dyed with a suitable dye system, which migrates sufficiently
- auxiliaries can aid levelness.

TESTING TO ENSURE ADEQUACY OF SCOURING

Soxhlet extraction

Soxhlet extraction

- Standard technique based on IWTO-10

WIRA rapid method

- total fatty matter (TFM) measurement in less than 15 minutes
- ideal for process control
- simple, compact, robust and efficient
- testing in fibres, yarn or fabric form
- suitable for all natural and synthetic fibres.

7 - **Module 3:** Preparing wool for dyeing

EXPLAIN THAT quality control checks are required to ensure the level of oils in the scoured material is less than 0.8% (on weight of fibre) and preferably less than 0.5% before dyeing is carried out. Residual extractable matter on garments is measured on a routine basis.

MENTION THAT two techniques are used to measure residual oils:

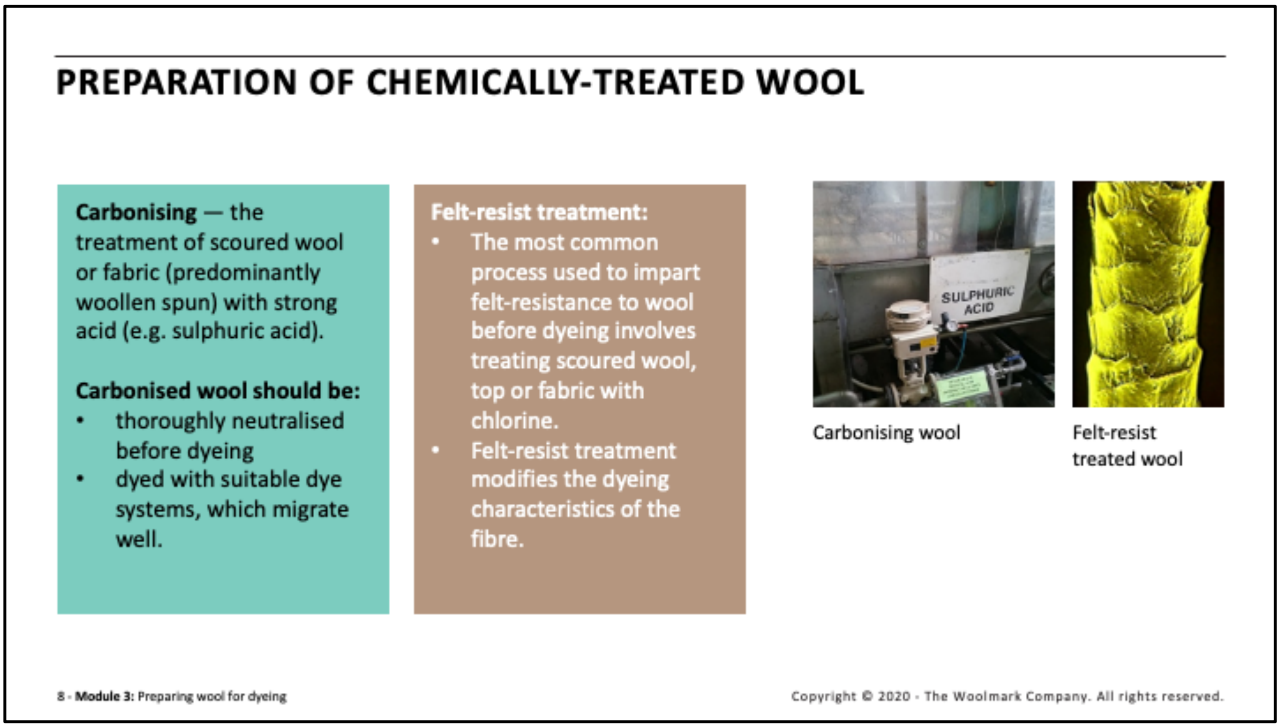
- Soxhlet extraction using dichloromethane (DCM)
- the 'WIRA rapid' method.

In both methods the DCM dissolves the extractable material on the wool and separates it from the fibres so it can be weighed.
The results of the WIRA test must be correlated with a standard reference test procedure based on Soxhlet extraction. A typical conversion equation is:

- Dichloromethane soxhlet = 1.2 x WIRA rapid value + 0.35

INDICATE THAT the validity of this conversion should be verified experimentally with the specific equipment and individual operators being used.

NOTE: In some countries the use of dichloromethane is banned. In these instances, petroleum ether or acetone have been used to extract the oils and waxes. Both these solvents are highly flammable so require extreme care during handling.



Carbonised wool

EXPLAIN THAT wool that has been carbonised (e.g. raw wool with high vegetable matter content**)** requires additional treatment before dyeing. Carbonising involves treating scoured wool or fabric with sulphuric acid to degrade any residual vegetable matter and remove the carbonised dust during subsequent processes.

NOTE THAT the pH of both loose wool and fabric after carbonising is low, which affects the affinity of dyes.

POINT OUT that carbonised wool should be thoroughly neutralised before dyeing. Soda ash or ammonia are conventionally used for neutralisation. Caustic soda can also provide a cost-effective system for adjusting pH. However, excessive additions of caustic soda will cause damage to the wool, so it must be used cautiously. The level of caustic soda used will depend on the acid content of carbonised fabric, but is generally around 1.0% or more.

Alternatively, carbonised wool may be dyed directly with dyes that are normally applied at a low pH and migrate well.

MENTION THAT the preparation of felt-resist treated wool will be discussed later in this course.

BLEACHING AS A PREPARATION FOR DYEING

Bleaching is required:

- to create a whiter raw material
- for products dyed to pale or bright shades.

The whiter the base wool the brighter the shade that can be produced.

9 - **Module 3:** Preparing wool for dyeing

INDICATE THAT wool is naturally cream in colour, due to the presence of coloured matter within the fibre. Bleaching can improve the whiteness of wool by removing colour from coloured species in the fibres.

HAND OUT *samples of bleached and unbleached wool to participants.*

ALLOW *time for participants to observe samples closely and comment on differences in look and handle.*

TAKE *two or three participant comments from across the room.*

EXPLAIN THAT for products that are to be dyed to pale or bright shades, bleaching creates a whiter base material, which gives brighter hue to the final colour. This is particularly important for blue dyes, the brightness of which is changed by any yellowness in the fibre.

NOTE THAT wool is usually whitened by bleaching immediately before dyeing. The whiter the base wool, the brighter the shade that can be produced.

CHEMISTRY OF BLEACHING

FIBRE TYPE	FIBRE STATE	YELLOWNESS	WHITENESS
		Index	Index
Wool	Natural	23.3	9.4
	Peroxide bleached	15.7	38
	Double bleached	13.4	45
Cotton	Bleached	5.2	73.4
Polyester		4.7	73.4

Source: Millington in *'Colouration of wool and other keratin fibres'*

Bleaching improves whiteness of wool by destroying the chromophore of the coloured matter in the fibre.

Methods of bleaching:

- oxidising agents (e.g. hydrogen peroxide)
- reducing agents (e.g. hydrosulphite and bisulphite)
- oxidative and reductive (two-stage bleaching).

10 - **Module 3:** Preparing wool for dyeing

NOTE THAT bleaching removes colour from coloured species in fibres. Wool of any colour can be bleached to improve its whiteness.

EXPLAIN THAT there are three types of method normally used:

- oxidative bleaching
- reductive bleaching
- combined oxidative and reductive bleaching, carried out in two stages (oxidative followed by reductive).

REFER participants to the table on the slide, which indicates the increase in whiteness (or reduction in yelllowness) that can be achieved. Note the comparison with cotton and polyester, which are much whiter base materials than wool.

POINT OUT that both oxidative and reductive bleaching processes cause some fibre damage, which must be controlled to maintain acceptable product and processing performance.

EXPLAIN THAT the most suitable bleaching methods are determined by:

- the initial colour of the wool,
- the degree of whiteness required
- the acceptable level of damage.

MENTION THAT often the level of whiteness demanded by customers is 'maximum'. For this reason, the limiting factors are predominantly initial wool colour and fibre damage.

Exposure to sunlight also bleaches wool — a process called **photo-bleaching.** As the period of exposure lengthens, the wool starts to yellow – a process called **photo-yellowing.**

NOTE: With extensive exposure to sunlight wool will yellow markedly. Photo-yellowing occurs more rapidly in wet wool.

BLEACHING OF WOOL — OXIDATIVE

Rapid bleaching

Acid pH~5	
Activator	2–6g/l
Wetting agent	1g/l
Hydrogen peroxide	10–30ml/l
80°C for 45–60mins	
Alkaline pH 8.5–9.0	
Clarite WO	4g/l
Invatex CS	1g/l
Hydrogen peroxide	25ml/l
45°C for 60mins	
Rinse and neutralise with acid to pH 5.5	

Traditional steep bleaching

Stabiliser	4g/l
Wetting agent	1g/l
Hydrogen peroxide	
40-50°C with circulation	
Stand 8–16hrs, rinse well	

11 - **Module 3:** Preparing wool for dyeing

INDICATE THAT hydrogen peroxide is the most widely used oxidative bleaching agent for wool. It is suitable for many different processes including:

- rapid bleaching under acid or alkaline conditions
- traditional steep bleaching
- continuous applications.

POINT OUT that alternative oxidising agents are available, but they are either prepared from hydrogen peroxide or are more expensive.

NOTE THAT the method used for steep bleaching of wool shown in the slide. This may be acid or alkaline.

MENTION THAT those methods or products with more aggressive oxidising activity can be used when bleaching stained or very yellow wools, for which the additional cost of the reagents may be justified.

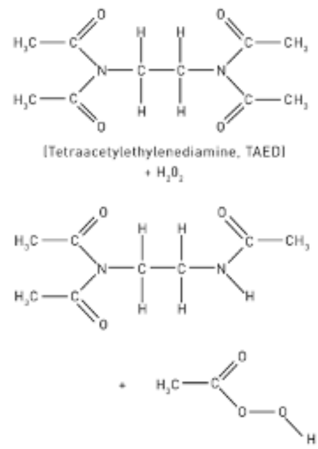
PEROXIDE AND ITS ACTIVATION AND STABILISATION

STABILISERS

To prevent catalytic breakdown of peroxide by metal ions:
- polyphosphates
- tetrasodium pyrophosphate,
- hexametaphosphates
- organic stabilisers
- silicates
- combinations of these products.

ACTIVATORS

- Organic acids
- Amides as acid precursors



http://www.rsc.org/learn-chemistry/resources/chemistry-in-your-cupboard/vanish/5

12 - **Module 3:** Preparing wool for dyeing

EXPLAIN THAT for hydrogen peroxide to provide effective bleaching under acid conditions it must first be activated.
Typical activators include organic acids, such as citric acid. A typical activator for wool bleaching and the chemistry of its action are shown in the slide.

NOTE THAT it is important to control this activation. Rapid and unregulated breakdown of the peroxide leads to increased fibre damage and wasteful use of the bleaching species.

Hydrogen peroxide is supplied in an acid-stabilised form by manufacturers, so its effective concentration is maintained for long periods in storage.

POINT OUT that catalytic breakdown of peroxide by metal ions leads to the formation of highly-reactive intermediates, which can also cause excessive fibre damage. The inhibition of spontaneous decomposition in the bleaching bath is also referred to as 'stabilisation'.

MENTION THAT control of the balance between peroxide activation and stabilisation during the bleaching operation is essential for achieving effectively bleached whites with minimum fibre damage.

INDICATE THAT stabilisers should have:
- some sequestering action to avoid catalytic breakdown by metal ions
- pH buffering action to maintain the optimum activation pH.

OXIDATIVE BLEACHING OF WOOL – ALTERNATIVE METHODS

Continuous loose wool bleaching:

- Final bowl of scour
- Hydrogen peroxide (10–35ml/l)
- Tetrasodium pyrophosphate
- Prestogen W (activator)
- Formic acid (pH=4.0–4.5)

Pad or store bleaching:

- Wetting agent (1g/l)
- Stabiliser
- Hydrogen peroxide (40–70g/l)
- Store (12–16hrs)
- Rinse

13 - **Module 3:** Preparing wool for dyeing

INDICATE THAT continuous wool bleaching is primarily carried out during loose wool scouring to increase the wool value. Price premiums for bleached (whiter) wools are greater than the costs of bleaching.

This form of bleaching also reduces the tendency to photobleaching, which can be important in wool products such as floorcoverings (i.e. carpets and rugs).

EXPLAIN THAT a serious negative aspect to the practice of raw wool bleaching to increase value is that buyers of the wool may be (and often are) unaware it has been bleached. Subsequent chemical processes, possibly further bleaching, can lead to unacceptable levels of fibre damage.

INDICATE THAT pad-store and pad-steam processes have also been developed for the bleaching of wool top, yarn in hank form and fabric. These processes involve pad application of the bleaching chemicals from aqueous solution followed by either storage (pad-store) or steaming (pad-steam) of the wet wool. The processes are completed by rinsing and drying.

POINT OUT that pad-store bleaching of tops or hanks with hydrogen peroxide (12–16 hours) has been practised but is too slow for modern production techniques. The process is completed by rinsing and drying.

MENTION THAT a system, named Lanapad, using radio frequency energy to heat the stored batch and reduce bleaching times to two hours, was also used for some time, but is no longer in use as it did not fit well into modern production methods.

EXPLAIN THAT while technically feasible, pad-steam processes are rarely used because machinery for steam processing is also often used for continuous dyeing or top printing. This creates a high risk of colour contamination and staining.

IMPACT OF IONIC SURFACTANTS ON OXIDATIVE BLEACHING

SLS	ACID		ALKALI	
Concentration (g/L)	Whiteness	Damage	Whiteness	Damage
0	28	14.5	31	16.8
0.29	28	13	33	15.5
2.9	30	12.8	34	14.5
29	33	10.5	36	13.5

CTMAB	ACID		ALKALI	
Concentration (g/L)	Whiteness	Damage	Whiteness	Damage
0	28	14.5	31	16.8
0.3	28	16	31	17
3	27	16	31	22
30	27	16	35	22.5

Kyungwha Oh, Myungja Park, Kyunghwa Hong, Colouration Technology 2008, 14 (11) 321

14 - **Module 3:** Preparing wool for dyeing

EXPLAIN THAT ionic surfactants, in sufficient concentration, modify the oxidative bleaching of wool under both acid and alkaline conditions. Research has shown that surfactants increase the whiteness of wool, the extent of the improvement depending on the structure of, and charge on, the surfactant.

REFER participants to the tables on the slide as you indicate that while anionic surfactants, such as sodium laurel sulphate (SLS) have a protective effect on the wool (reduce damage), the cationic surfactants, such as cetyl trimethyl ammonium bromide (CTMAB) accelerate the damage. In this case, damage is measured as the alkali solubility of the wool (i.e. the higher the number the greater the damage).

NOTE THAT the chain length of the alkyl group on an ionic surfactant increases the protective effect. Anionic surfactants with a greater chain length have a greater protective action.

BLEACHING OF WOOL — REDUCTIVE

Batchwise

- sodium dithionite 2–5g/l (Hydros)
- other sulphinic acid derivatives
  - sodium formaldehyde sulphoxylate
  - zinc formaldehyde sulphoxylate
  - sodium borohydride/sodium bisulphite.

Continuous

Pad to approximately 100% pick-up with:

- wetting agent 2–10 g/l
- Blankit DZ 20–150 g/l
- formic acid 10 g/l
- steam (saturated at 102°C) for 10–30 minutes
- rinse.

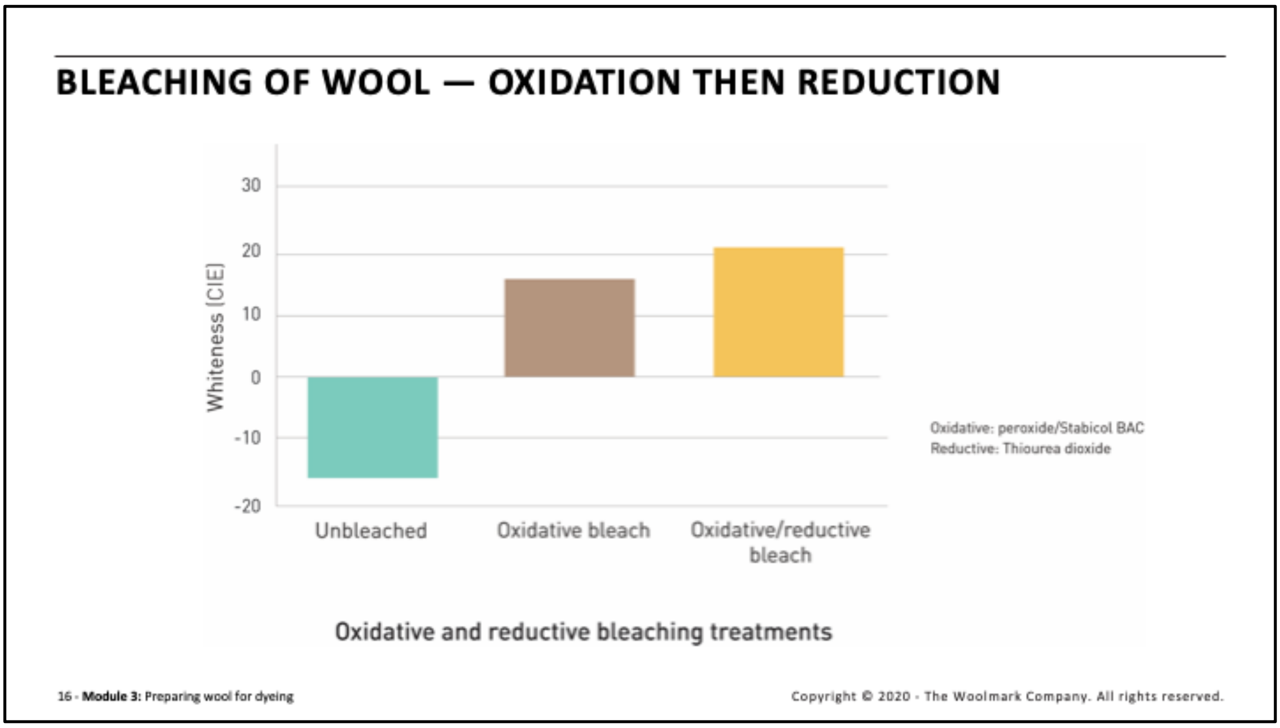
15 - **Module 3:** Preparing wool for dyeing

INDICATE THAT methods for both batchwise and continuous reductive bleaching are shown on the slide.

POINT OUT that the bleaching agents commonly used for reductive bleaching are:

- sodium dithionite (also called sodium hydrosulphite or Hydros)
- thiourea dioxide
- sodium borohydride (called Colour Clear [Rohm and Haas])
- some other sulphinic acid derivatives.

NOTE THAT all reductive bleaching is followed by a peroxide rinse to remove any residual reducing agent.



EXPLAIN THAT even with the best oxidative bleaching processes there is a limit to the whiteness that can be achieved without inflicting unacceptable levels of fibre damage.

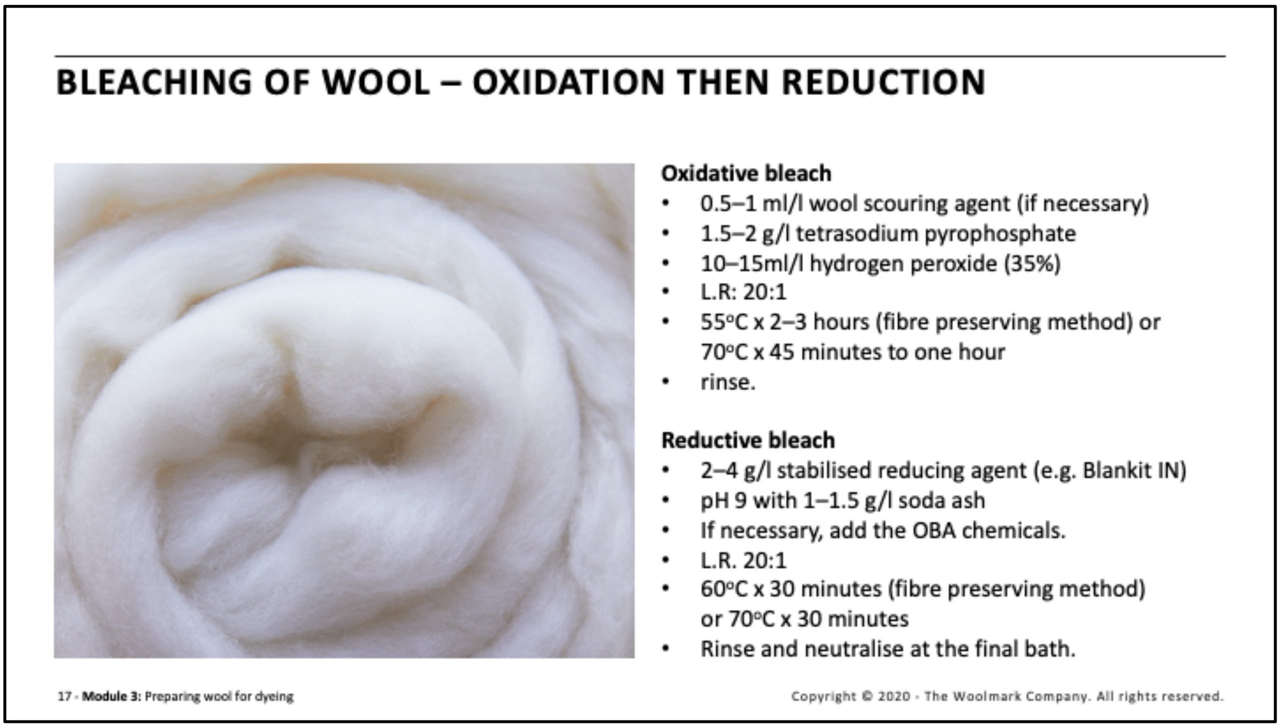
NOTE THAT sequential oxidative and reductive bleaching treatments have been found to impart even higher levels of whiteness while minimising damage as illustrated on the slide.

Rapid hydrogen peroxide methods are normally employed for the oxidative step. Traditional reductive bleaching is carried out as a second step.

Fluorescent whitening

INDICATE THAT a further possibility to whiten wool is the application of fluorescent whitening agents during a reductive bleaching cycle. Combined reductive bleaching agents and fluorescent whiteners are commercially available.

NOTE: Fluorescent whiteners accelerate the subsequent photo-yellowing of wool.



REFER participants to the recipes for the two-stage process as shown on the slide:

NOTE in the oxidative bleaching step:

- the optional pre-scour of the wool to remove any residual oils
- the stabiliser used is tetrasodium pyrophosphate
- the options for time and temperature.

NOTE in the reductive bleaching step:

- the use of a stabilised reducing agent
- the optional use of optical brightening agents
- the options for time and temperature.

EXPLAIN THAT neutralisation involves the use of dilute acid to lower the pH and (optionally) dilute peroxide to remove any residual reducing agent.

BLEACHING HEAVILY-PIGMENTED WOOL

Coloured wool is widely used in the craft industry and is prized for its natural colour.

A mordant bleaching method is used when it is necessary to bleach coloured wool:

- The wool is first mordanted with an iron salt.
- Ferrous ion complexes with coloured species.
- Excess ferrous ions are rinsed from the fibre.
- The wool is bleached with peroxide:
    - the ferrous ions catalyse the decomposition of the peroxide
    - the coloured species are destroyed by radical attack.

18 - **Module 3:** Preparing wool for dyeing

INDICATE THAT heavily-pigmented wool, such as karakul and even some human hair used in wigs, can be bleached using a mordanting method.

The effect of metal ions during bleaching is used to advantage in mordant bleaching of stained, pigmented or dark-fibre-contaminated wools.

EXPLAIN THAT the colouring agent in pigmented wools is melanin. Bleaching these fibres requires destruction of the melanin, which is normally achieved by iron-catalysed hydrogen peroxide bleaching.

The method

- The wool is first mordanted with an iron salt; typically ferrous sulphate.
- The ferrous ion complexes with coloured species.
- Excess ferrous ions are rinsed from the fibre in the presence of a reducing agent.
- The wool is bleached with peroxide. The peroxide decomposes under the catalytic action of the metal salts near the coloured material. The coloured species is destroyed by radical attack.

***HAND OUT** unbleached and bleached samples of heavily pigmented wool to participants.*

***ALLOW** participants time to observe samples closely and comment on differences in look and handle.*

***TAKE** two or three participant comments from across the room.*

DARK FIBRE BLEACHING

WOOL TYPE	BLEACHING METHOD
Good-to-average colour	Oxidative or, for maximum whiteness, combined oxidative/reductive
Poor colour or stained	Oxidative/enhanced reductive
Pigmented wools or white wools with dark fibre contamination	Mordant/oxidative

Mordant
- Set the bath at 40°C with:
  - ascorbic acid (or erythorbic acid) 4.0–6.0 g/l
  - ferrous sulphate 3.0–6.0 g/l
- Raise to 90°C and run 30 minutes.

Rinse
- Rinse 20 minutes at 80°C with:
  - ascorbic/erythorbic acid 0.5 g/l
- Rinse 20 minutes cold.

Bleach
- Set with:
  - tetrasodium pyrophosphate 8.0 g/l
  - hydrogen peroxide (35%) 8.0-15.0 ml/l
- Raise to 70°C and run 30–60 minutes.
- Rinse and acid sour to pH 5.0 with acetic acid.

19 - **Module 3:** Preparing wool for dyeing

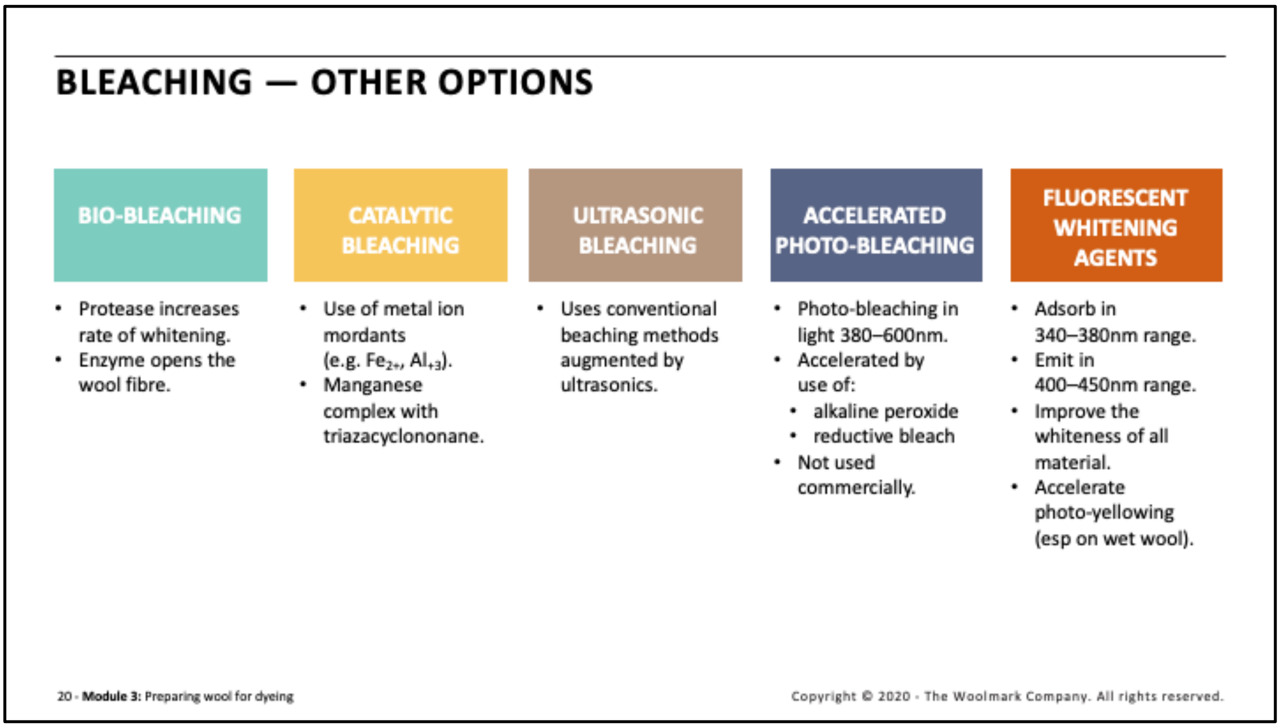
INDICATE THAT the mordant method can only be used on those wools contaminated with naturally pigmented dark fibre. The process normally has no effect on dyed fibre contaminants.

EXPLAIN THAT the mordant method is also not relevant to loose wool or tops, where it is more cost effective to buy better wool than to undertake this expensive bleaching process. Mordant bleaching is most useful for 'rescuing' yarn, fabric or knitwear that is inadvertently contaminated with coloured fibre and would otherwise be unfit for the prescribed end use.

NOTE THE recipe for mordant bleaching is shown in the above slide:

Two methods are available:
- conventional (shown on the slide)
- phosphate-free.

POINT OUT that both follow the same basic procedure:
- Mordant with Fe_2+ salt to fix iron in the melanin granules.
- Rinse to remove iron from the wool (keratin) matrix.
- Bleach with hydrogen peroxide to catalytically destroy the melanin pigment.



MENTION THAT during recent years newer methods of bleaching have been developed to:

- increase the rate of bleaching
- improve the balance between whiteness and damage.

Bio-bleaching uses a pre-treatment with an enzyme to open up the fibre and allow more rapid bleaching.

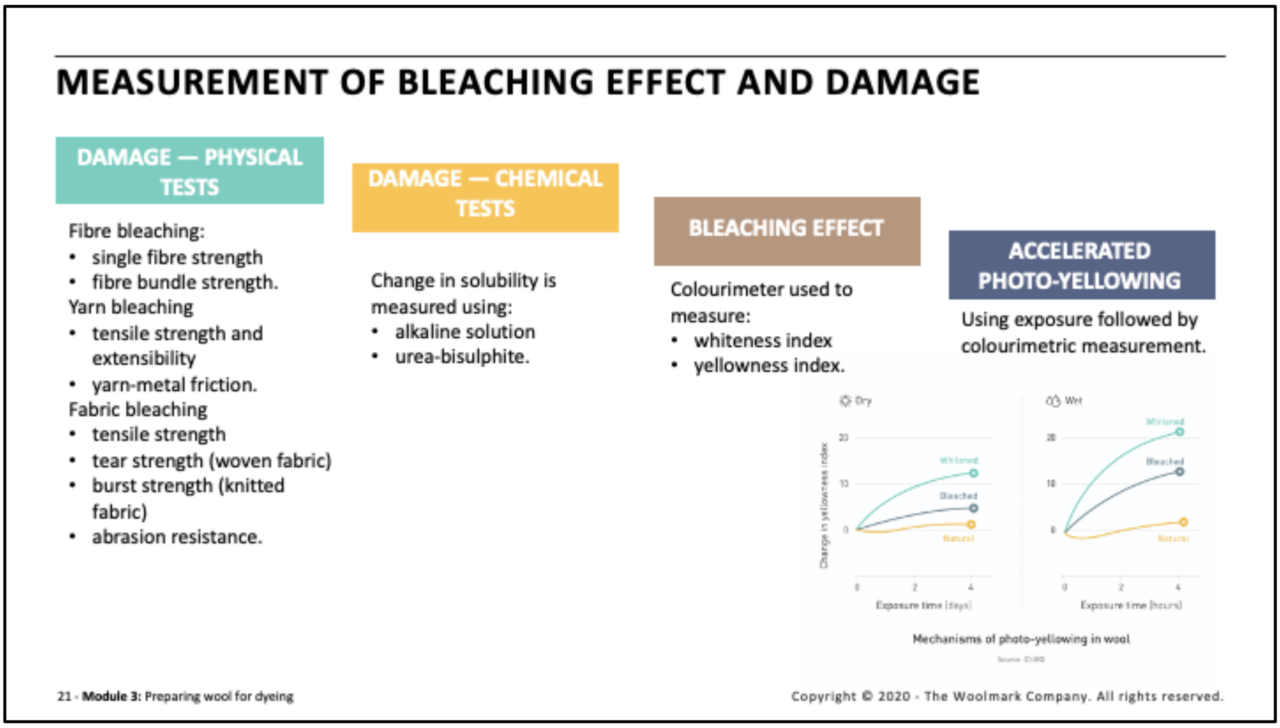
New mordants (catalytic bleaching) have found to improve bleaching of pigmented wool.

Ultrasonic bleaching uses conventional bleaching methods augmented by ultrasonics.

Accelerated photo-bleaching In the early stages of exposure, light will bleach wool. Further exposure causes yellowing. Peroxide can be used to accelerate the photo-bleaching stage.

Fluorescent brightening agents are used to improve the whiteness of many fibre types. These products:

- adsorb in 340–380nm range
- emit in 400–450nm range
- improve the whiteness of all material
- accelerate photo-yellowing (especially on wet wool).



POINT OUT that the balance achieved between whitening and the damage inflicted during the bleaching process is of critical commercial importance.

NOTE THAT the test methods used to measure this damage depend on the form of the fibre (loose, top etc.)

INDICATE THAT as outlined on the slide, damage to the fibre during bleaching can be measured using physical tests from:

- the strength of the fibres
- the strength of the yarn
- the strength or abrasion resistance of fabric.

Damage can be measured chemically as the change in solubility of the wool in various reagents including:

- alkali solubility IWTO DRAFT TM-4-2000
- urea-bisulphite solution IWTO DRAFT TM-11-99.

Other methods to measure solubility in these reagents are also available.

EXPLAIN THAT whiteness is measured spectroscopically. While a number of measures are used, two measures are most popular:

- Yellowness index is determined from the tristimulus values obtained from reflectance measurements:
  - YI = Y-Z as IWTO-56 (2003)
  - YI = (aX-bZ)/ Y as ASTM 313
- Whiteness index — a number of formulae are used.

POINT OUT that the graphs on the slide show the photo-yellowing of bleached and unbleached wool. The previously mentioned accelerated photo-yellowing of wool treated with optical brightening agents is clearly visible.

The initial photo-bleaching of unbleached wool can also be seen in this diagram.

NOTE THAT damage during bleaching can be further exacerbated during dyeing. This will be covered in later modules.

SUMMARY — MODULE 3

- The history and preparation of wool for dyeing
- Normal scouring is adequate for most undamaged wool products
- Chemically treated loose wool or top must be well blended
- Any fabrics that have been piece carbonised
  - dyed with conventional 1:1 metal complex dyes
  - thoroughly neutralised prior to dyeing
- To achieve bright colours wool is bleached before dyeing
- There are three types of bleaching procedures
  - reductive bleaching
  - oxidative bleaching
  - oxidative then reductive bleaching
- Naturally pigmented fibre can be bleached using an iron mordanting process
- Fibre damage in bleaching can be exacerbated by subsequent damage in dyeing.

22 - **Module 3:** Preparing wool for dyeing

REVIEW THE fact that dye uptake and affinity are affected by:
- the history of wool to be dyed
- the methods of preparation of wool for dyeing.

Normal scouring is adequate for most undamaged wool products, provided it reduces the contaminant level (oils and waxes) to an acceptable level.

REMIND participants that chemically-treated loose wool or top must be well blended to ensure any potential differences in dye affinity between parts of the wool are properly addressed. Such blends should be dyed with systems that ensure levelness (i.e. dyes with sufficient migration or the use of levelling agents).

REITERATE THAT any fabrics that have been subjected to piece carbonising (predominantly woollen spun) should be either:
- thoroughly neutralised prior to dyeing,
- dyed with suitable levelling dyes.

REVIEW THE fact that to achieve pale or bright colours, wool is bleached to provide a better base colour for dyeing.

SUMMARISE THE three types of bleaching procedures:
- reductive bleaching
- oxidative bleaching
- two-stage bleaching (oxidative then reductive bleaching).

Naturally-pigmented fibre can be bleached using an iron-mordanting process before bleaching.

REITERATE THAT fibre damage during bleaching can be exacerbated by subsequent damage in dyeing. Damage can be assessed through a number of methods.

***ASK** participants if they have any questions about the content covered in this module.*

***ALLOW** time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants of the time and location for the next lecture — *Module 4 Selecting and applying wool dyes*— and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

THE WOOLMARK COMPANY

MODULE 4

SELECTING AND APPLYING WOOL DYES

RESOURCES — MODULE 4: SELECTING AND APPLYING WOOL DYES

No additional resources are required to deliver **Module 4: Selecting and applying wool dyes**.

WELCOME participants to Module 4 of the Wool Science, Technology and Design Education Program *— The dyeing of wool —Selecting and applying wool dyes*

EXPLAIN THAT this module will explore the selection and implication of a suitable dye type for a given purpose, the use of dye auxiliaries, and the methods and recipes used to apply dyes at various stages of the wool processing pipeline.

INFORM participants that by the end of this module they will be able to:

- list the criteria used to select wool dyes for a particular application
- explain the implications of the choice of dye for subsequent product performance
- describe the auxiliary products used in wool dyeing (the reasons and dangers)
- describe the recipes used to apply individual dye types
- explain the rationale for the recipes used
- appreciate the issues associated with trichromatic dyeing.

NO RESOURCES REQUIRED FOR THIS MODULE

TYPES OF WOOL DYES

Acid dyes (three broad types):
- levelling acid dyes
- milling acid dyes (Class one)
- milling acid dyes (Class two)

Reactive dyes
- react (form covalent bonds) with protein molecules

Pre-metallised dyes are:
- anionic dyes in which the chromophore is pre-formed during manufacture of the dye by a metal ion (usually chromium)
    - 1:1 pre-metallised dyes — metal ion complexed with one dye molecules
    - 1:2 pre-metallised dyes — metal ion complexed with two dye molecules

Chrome dyes:
- are a mordant dyeing system.

2 - **Module 4:** Selection and application of wool dyes

INDICATE THAT as previously discussed in *Module 3 Preparing wool for dyeing*, there are four groups of dyes used for dyeing wool.

Acid dyes
- are anionic dyes, which are widely used.
- vary in molecular weight and colour range
- are generally classified into three (or optionally four) groups as shown on the slide. The Society of Dyers and Colourists (SDC) recognises four groups of acid dyes, based on the pH of application.

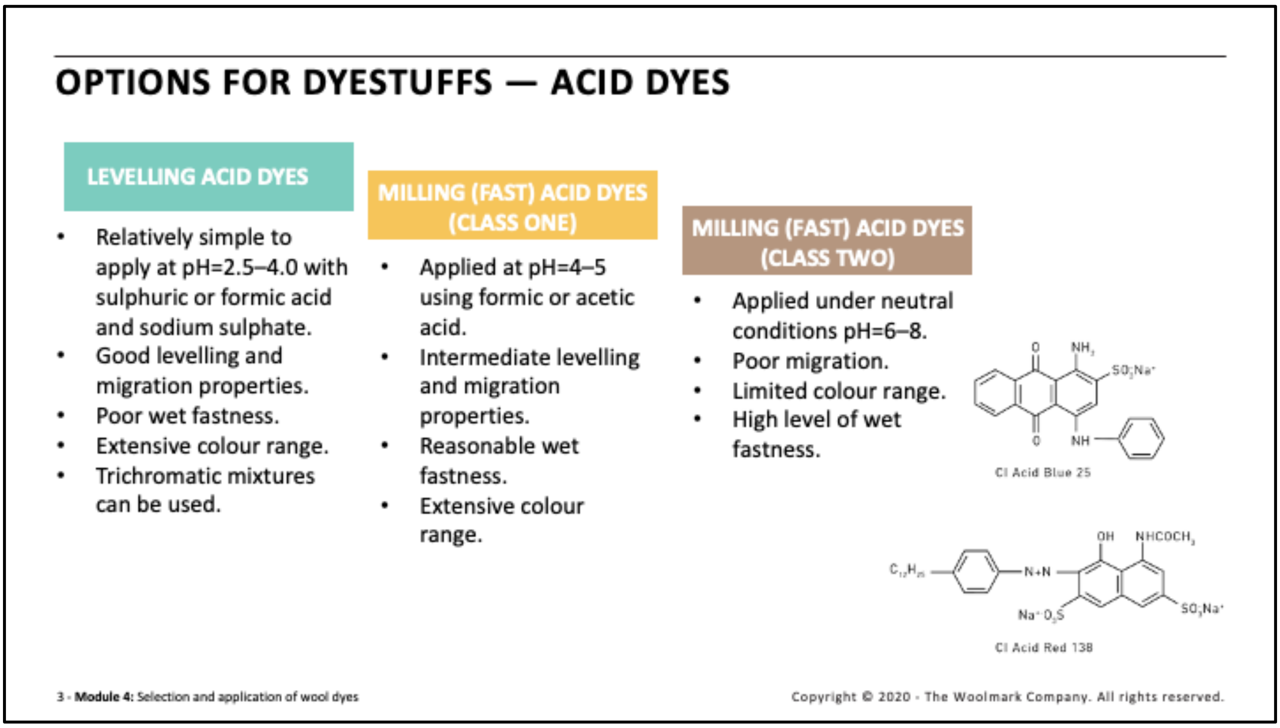
POINT OUT that in this course three groups will be recognised:
- levelling acid dyes:
- milling acid dyes (Class one)
- milling acid dyes (Class two) sometimes called 'super-milling dyes'

Reactive dyes are anionic dyes with an electrophilic reactive group (often an activated double bond), which can react with nucleophilic sites within the wool fibre.

The pre-metallised dyes are a form of acid dye, but the chromophore is a metal complex (usually chromium), which is formed during production of the dyestuff. These dyes are sometimes called 'metal complex' dyes.

NOTE THERE are two types of pre-metallised dyes:
- 1:1 pre-metallised dyes – metal ion complexed with one dye molecules
- 1:2 pre-metallised dyes – metal ion complexed with two dye molecules.

Chrome dyes are a mordanting dyeing system, which relies on the use of chromium salts or complexes.



EXPLAIN THAT levelling acid dyes are relatively simple to apply at low pH, have good levelling and migration properties. They have poor wet fastness and can bleed during subsequent wet processing of fabric or garment.
These dyes have an extensive colour range — trichromatic mixtures can be used. Levelling acid dyes are recommended for use during later stages of wool processing where a high level of wash fastness is not required (e.g. dry clean only products). They can be applied to:

- fabric — piece dyeing
- garments — garment dyeing.

EXPLAIN THAT milling (fast) acid dyes (Class one) consist of larger-molecular-weight dyes and are normally applied at pH=4-5. They have intermediate levelling properties, reasonable wet fastness and an extensive colour range.

EXPLAIN THAT milling (fast) acid dyes (Class two) are applied under neutral conditions, have poor migration and levelling properties but a high level of wet fastness. These dyes are sometimes called ‘super-milling dyes’ or ‘neutral dyeing acid dyes’. They are not recommended for yarn, fabric or garment dyeing. The rate of temperature rise during dyeing must be carefully controlled.

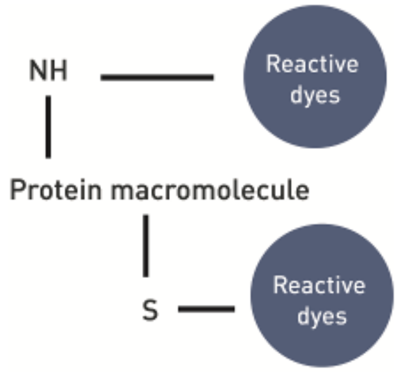
INDICATE THAT these dyes have a more limited colour range and are recommended for use in loose stock dyeing where a high level of wash fastness is required.

POINT OUT that the structure of two acid dyes is shown in the slide.

OPTIONS FOR DYESTUFFS — REACTIVE DYES

Reactive dyes

- Good migration before fixation.
- Recommended where high levels of wash fastness are required.
- Bright colours available.
- React with dye sites by nucleophilic substitution.



4 - **Module 4:** Selection and application of wool dyes

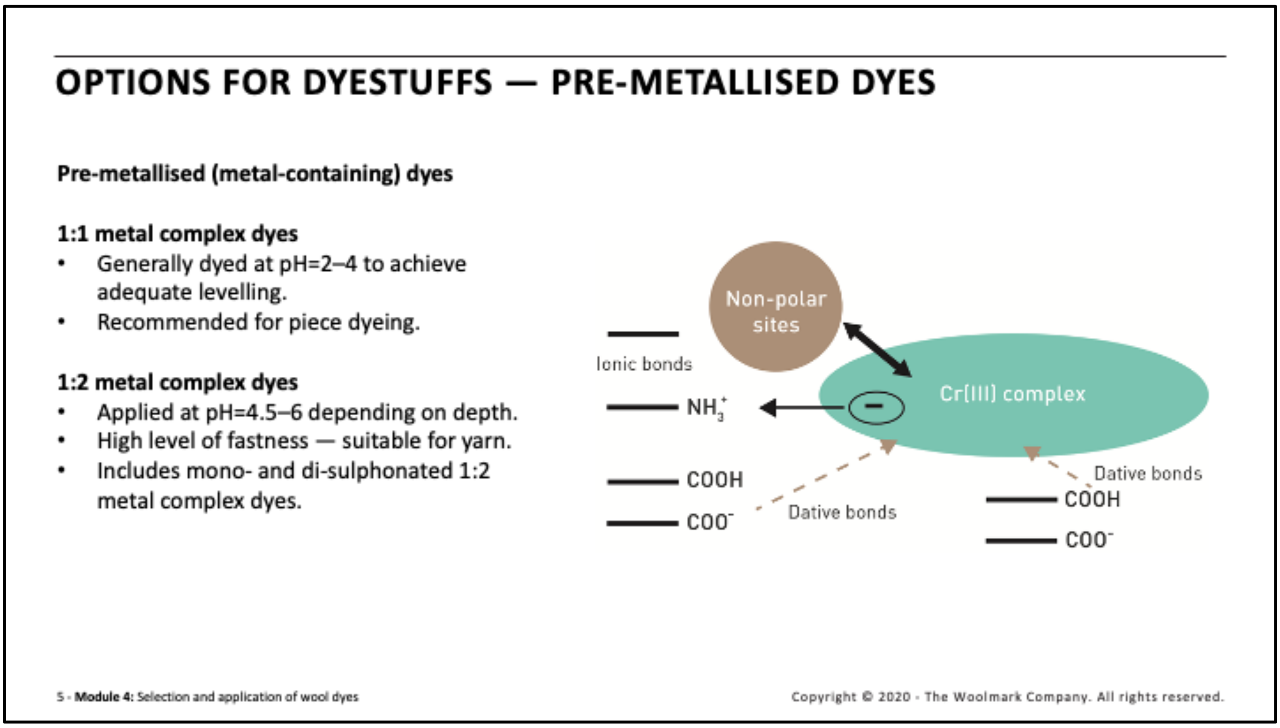
EXPLAIN THAT reactive dyes form covalent bonds with amino groups and thiol side chains by nucleophilic substitution.

EXPLAIN THAT the covalent bonding prevents the subsequent migration of the dye molecules and ensures a high level of wet fastness.

INDICATE THAT these dyes can react with nucleophilic groups on the outer layers of the wool fibre (particularly in the endocuticle region of the fibre) inhibiting their further migration into the centre of the fibre.

MENTION THAT trials with reactive, less reactive and non-reactive forms of the same dye demonstrated that:

- only the non-reactive dye fully penetrated the fibre
- the more reactive forms tended to 'ring dye' – dye the outside layers of the fibre with little penetration to the middle of the fibre
- a compromise is required between the rate of reaction and migration — a feature dye manufacturers have addressed in the dye structure and recipe.



EXPLAIN THAT pre-metallised dyes were developed to maintain the excellent fastness of chrome mordant dyeing without the complexities and problems with the mordanting process. Chromophores which include a metal ion generally have good light fastness.

REFER participants to the different forms of bonding that occur with pre-metallised dyes on wool as illustrated on the slide (the dashed arrows indicate dative bonds).

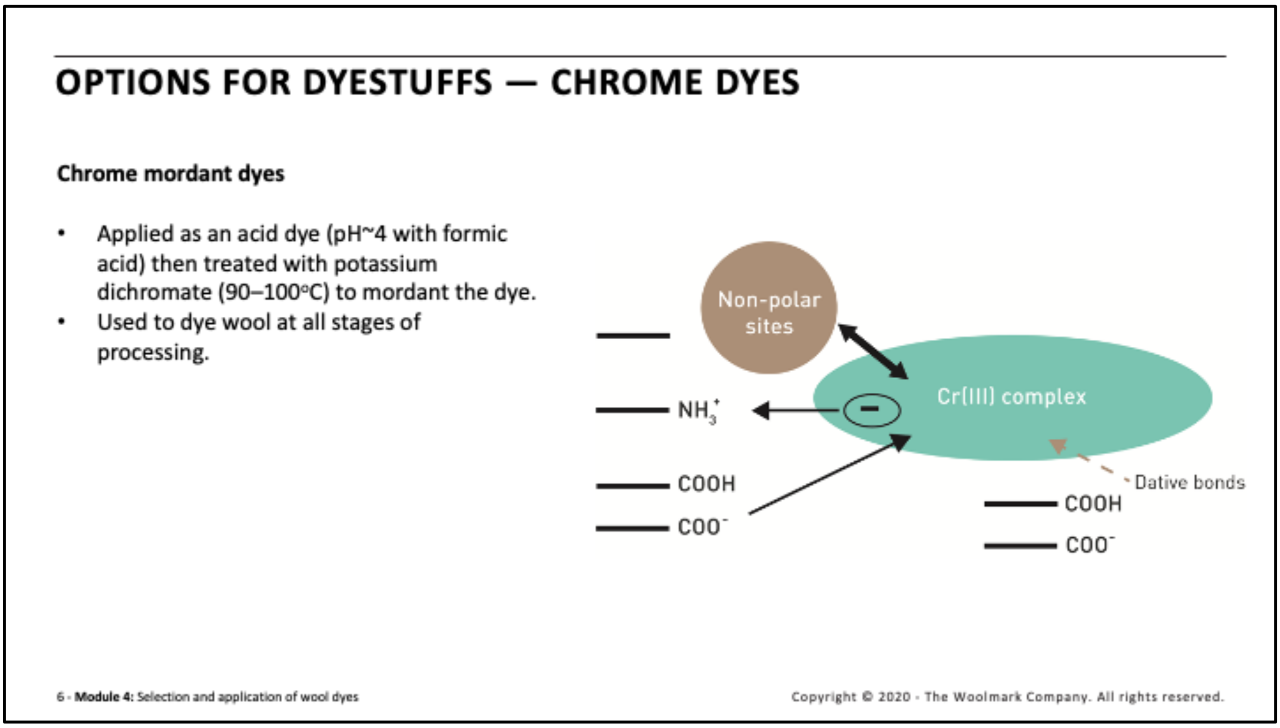
NOTE THAT two classes of pre-metallised are used:
1:1 pre-metallised dyes — These dyes have good levelling properties, a reasonable level of fastness and are generally applied under strong acid conditions. A range of 1:1 pre-metallised dyes (Neolan P – Huntsman) that can be applied at pH=3.5–4.0 were developed for piece dyeing to limit fabric damage.

INDICATE THAT these dyes do not include very bright shades — the complexity of the chromophore favours deeper shades.

1:2 pre-metallised dyes — These dyes were developed in the 1950s. They are applied under neutral or slightly acid conditions (pH=5.5–7.0) and come as mono-sulphonated and di-sulphonated types. These dyes require special auxiliaries to assist levelling, but have good light and wash fastness. These dyes can be used on a wide range of products including products that require fastness to machine washing.

EXPLAIN THAT 1:2 pre-metallised dyes also have variations called 'sulphonated 1:2 pre-metallised dyes'. The degree of sulphonation (mono- or di-) varies with the manufacturer's range. Sulphonation involves substituting a sulphonic acid group on the dye molecule. These dyes can be applied at lower pH, nearer the isoelectric point.

Examples of 1:2 pre-metallised dyes include:
- Lanasan (Clariant)
- Supralan (DyStar)
- Lanaset (Huntsman) – sulphonated.



INDICATE THAT chrome dyes are among the most widely used in wool dyeing (at the time of writing) and can be used at any stage of the wool processing route.

The process involves mordanting acid dyes using a chromium salt.

POINT OUT that the different forms of bonding that occur with chrome mordant dyes on wool are illustrated on the slide (the dashed arrow indicates a dative bond).

EXPLAIN THAT three methods can be used to apply these dyes:

- **pre-chrome** in which the wool is pre-treated with a chromium salt (usually potassium dichromate) and then dyed
- **after-chrome** in which the wool is dyed then treated with the chromium salt
- **meta-chrome** in which the dyeing and mordanting occur in the same batch.

NOTE THAT the after-chrome method is most widely used as it gives the best fastness and least damage to the fibre.

MENTION THAT the pre-chrome process damages the fibre, presumably as a result of oxidative attack on the macromolecules by the dichromate used.

OPTIONS FOR DYESTUFFS

Substrate:
- Wool (normal or chemically-treated)
- Blend
- Form of wool

Colour and intensity:
- Bright shades or deep shades (navy and black)

Fastness requirements:
- Product: milled or not milled
- Product: washable or dry clean only

Ease of dyeing:
- Form of wool
- Machine type available

Cost

7 - **Module 4:** Selection and application of wool dyes

EXPLAIN THAT the choice of the dyeing system used for wool depends on the following factors:

Substrate
- Wool (normal or chemically-treated)
- Blend
- Form of wool (i.e. loose wool, top, yarn, fabric, garment)

Colour and intensity required
- Bright shades or deep shades (navy and black).

Fastness requirements of the final product
- Product: milled or not milled.
- Product: washable or dry clean only.

Ease of dyeing
- Form of wool (i.e. loose wool, top, yarn, fabric, garment)
- Machine type available

Cost

The costs associated with dyeing vary with:
- the substrate (untreated wool or chemically treated wool)
- the form of the substrate (yarn, fabric etc)
- the type of dye required to achieve migration and fastness targets.

For example:

Weaving yarns are required to be fast to wet processing.

Worsted yarns
- 1:2 metal complex, acid milling, chrome or reactive dyes will be suitable.
- For black and navy shades, chrome and reactive dyes are mainly used
- For many duller pale and medium shades modified 1:1 metal complex have sufficient wet fastness and the advantage of very good levelness.

Woollen weaving yarns
- Dyed using acid milling, 1:2 metal complex, chrome or reactive ranges
- For higher levels of wet fastness, modified 1:1 metal complex dyes which offer better fastness with good levelling when applied with specific levelling agents can be used.

AUXILIARIES USED IN WOOL DYEING — pH CONTROL

Acid:
- Sulphuric acid for pH = 2–3
- Formic or acetic acid for pH = 3–4
- Acetic acid – acetate for pH = 5–7

Alkali:
- Sodium hydroxide
- Sodium carbonate

Alkaline salts used for pH adjustments and buffering:
- Sodium acetate
- Sodium bicarbonate

Continuous pH adjustment:
- Ammonium acetate

8 - **Module 4:** Selection and application of wool dyes

EXPLAIN THAT a wide range of auxiliaries is used in wool dyeing. These auxiliaries are generally added before the dye to allow them to equilibrate with the product being dyed (i.e. wool). At 40°C dyeing auxiliaries need at least 10–15 minutes circulation in the dyebath to achieve uniform distribution and equilibration with the product.

pH adjustment

NOTE THAT the pH of dyeing is critical for wool products as it has a major effect on adsorption and levelling.

INDICATE THAT the appropriate dyebath pH is generally achieved using acids and/or alkali or their salts. Acid-salt buffering systems are commonly used. The large number of acid and basic sites in the fibre mean there can be differences between the pH of the fibre and the dyebath.

POINT OUT that selected salts can be used to adjust the pH of the dyebath slowly as one of the components (normally ammonia) volatilises.

AUXILIARIES USED IN WOOL DYEING — LEVELLING

Levelling agents are used to retard dyeing rate by:

- competing for dye sites with dyestuff
- blocking dyes sites on the fibre (temporary or permanent)
- forming weak complex with dye molecules.

9 - **Module 4:** Selection and application of wool dyes

INDICATE THAT levelness takes many forms:

- The yarn on the inside of the package may different in hue to that on outside.
- Piece goods may be patchy or stripy. Edges may differ from the bulk of the fabric.
- In garments, seams may be different from the rest of the garment.

An unlevel dyeing can result from:

- poor preparation of wool
- an unsuitable dyeing procedure.

MENTION THAT to achieve levelness it necessary to control the exhaustion of dyes (particularly the initial rate or 'strike').

Options include controlling the rate of temperature rise, but this approach is only partially effective and the use of levelling agents is preferred

Levelling agents:
EXPLAIN THAT these reagents promote levelling by different mechanisms including:

- competing with the dyes for dye sites (includes sodium sulphate)
- blocking dye sites on the fibre either temporarily or permanently, acting like colourless dyes
- forming weak complexes with the dye to keep it in solution longer, only gradually releasing it to be absorbed by the fibre.

Some cationic materials can:

- precipitate the dye
- cause poor dyebath exhaustion
- lead to poor rub fastness.

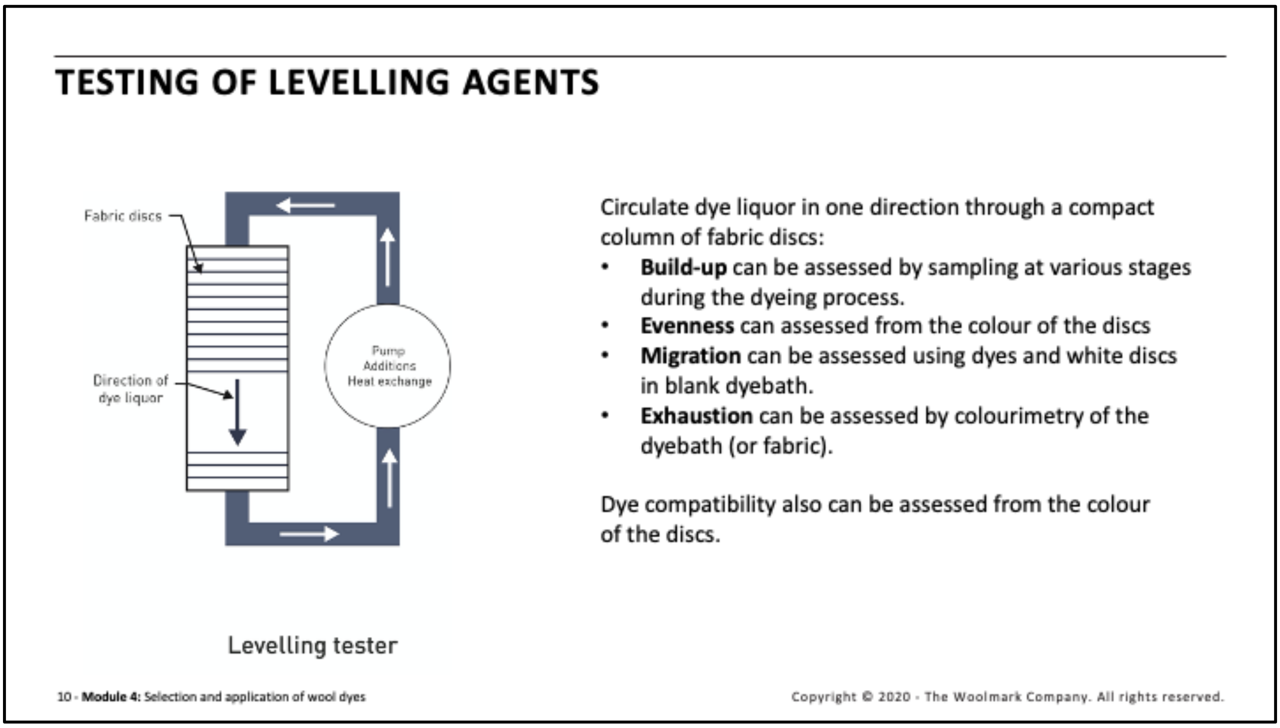
NOTE THAT a number of levelling agents can be used to eliminate root–tip effects by controlling the rate of adsorption of the dye:

- Lyogen SU liquid for Lanasyn S dyes
- Lyogen SU liquid for Sandolan milling N dyes
- Lyogen SMK liquid
- Albegal B (Huntsman).

The type and amount of levelling agent required depends on the nature of dye being used and its application level.

Levelling agents can affect the fibre, the hue of the dye, or both.

EXPLAIN THAT levelling agents are critical in the coverage of intra-fibre or affinity differences. Too little levelling agent can lead to unlevel and/or skittery dyeings. Too much can lead to 'reverse skitteriness'.



EXPLAIN THAT the efficacy of a levelling agent can be evaluated in a number of ways prior to its application in the dyehouse.

A useful test that can be used is shown on the slide.

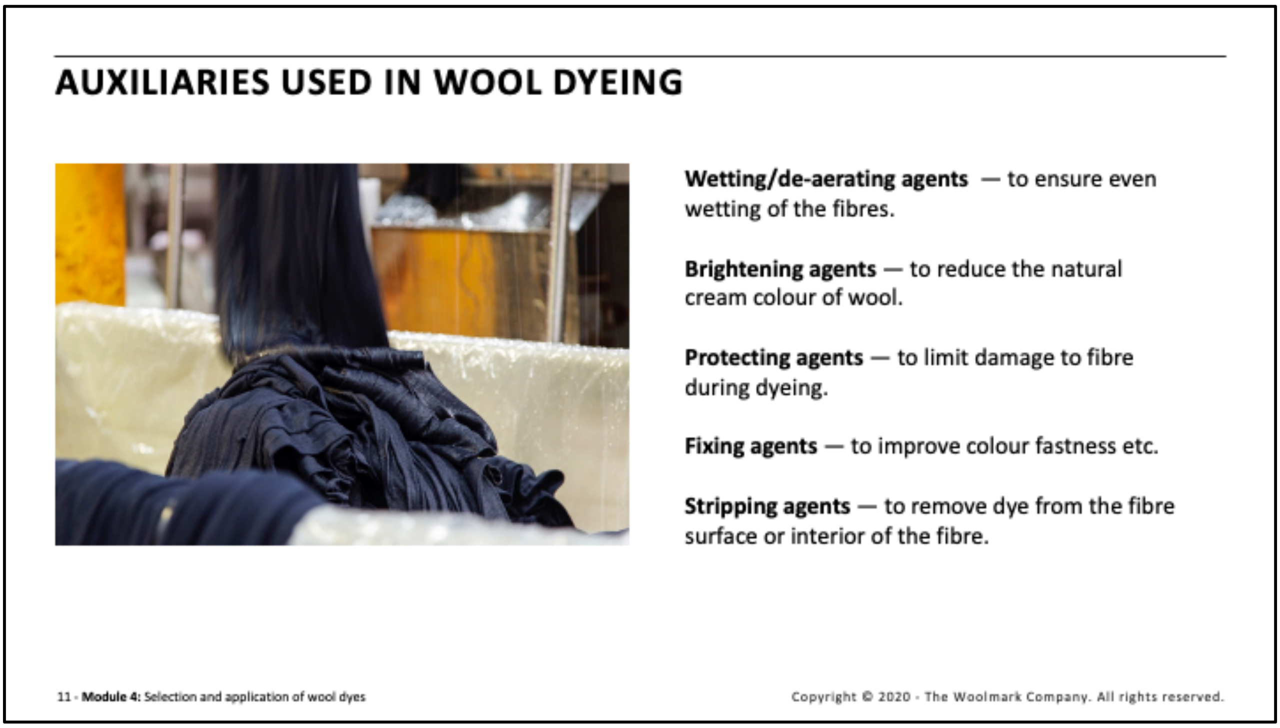
- Prepare a compact column of fabric discs.
- Circulate the dye liquor in one direction through the column of fabric.

Build-up of dyes can be assessed by sampling at various stages during the dyeing process.

INDICATE THAT at the end of the dyeing:

- **evenness** can be assessed by comparing the colour of the discs at each end of the stack
- **migration** can be assessed using white discs in blank dyebath
- **exhaustion** can be assessed by colourimetry of the dyebath (or fabric).

NOTE THAT dye compatibility also can be assessed from the colour of the discs.



Wetting/de-aerating agents
NOTE THAT these reagents are helpful in tightly-set fabrics on which liquor penetration can be difficult. They are generally anionic or non-ionic surface active agents.

Brightening agents
EXPLAIN THAT brightening agents ‘lift’ colour of pale shades. Typically hydroxylamine salts and bisulphite-based products are used, which give the wool a mild bleach.
The products cause less whitening and less fibre damage than conventional bleaching and may also inhibit yellowing during dyeing. They are normally added at end of the dyeing cycle, but can react with some reactive dyes, limiting range of dyes with which they can be used.

Wool protective agents
MENTION THAT wool fibres are damaged during dyeing. These agents can be used to limit this damage. (This will be discussed later in this course.)

Fixing agents
POINT OUT that fixing agents are designed to improve the wet fastness of products (esp. deeper shade garments). They commonly involve cationic after-treatments, which form a cationic layer on fibre preventing dyes from migrating out during washing. These products are often used for milling acid or 1:2 metal complex (including sulphonated) dyes.

Non-ionic and cationic mixtures are also used as fixing agents.

Stripping agents
INDICATE THAT stripping agents are designed to remove the dyestuff from the fabric. Their action can be controlled to remove only surface dye, which may affect rub fastness.

The range of stripping agents commonly used includes:
- zinc formaldehyde sulphoxylate
- other reducing agents
- polyethoxylated quaternary ammonium compounds at pH=8.

AUXILIARIES USED IN WOOL DYEING (CONTINUED)

Sequestering agents:
- remove metal ions from the dyebath
- cannot be used with pre-metallised dyes

Antifoams:
- prevent foaming in the dyebath

Lubricants:
- ensure even running of fabric in piece dyeing machinery
- reduce fibre-to-fibre and fibre-to-metal friction to allow easier movement of the fabric in piece dyeing machines

Dispersants:
- improve dyestuff solution of dispersion.

12 - **Module 4:** Selection and application of wool dyes

Sequestering agents

EXPLAIN THAT these reagents remove metal ions from the dyebath, which can interfere with dyes or damage the wool. They cannot be used for some pre-metallised dyes as they strip the metal from the chromophore, changing the colour.

Antifoams

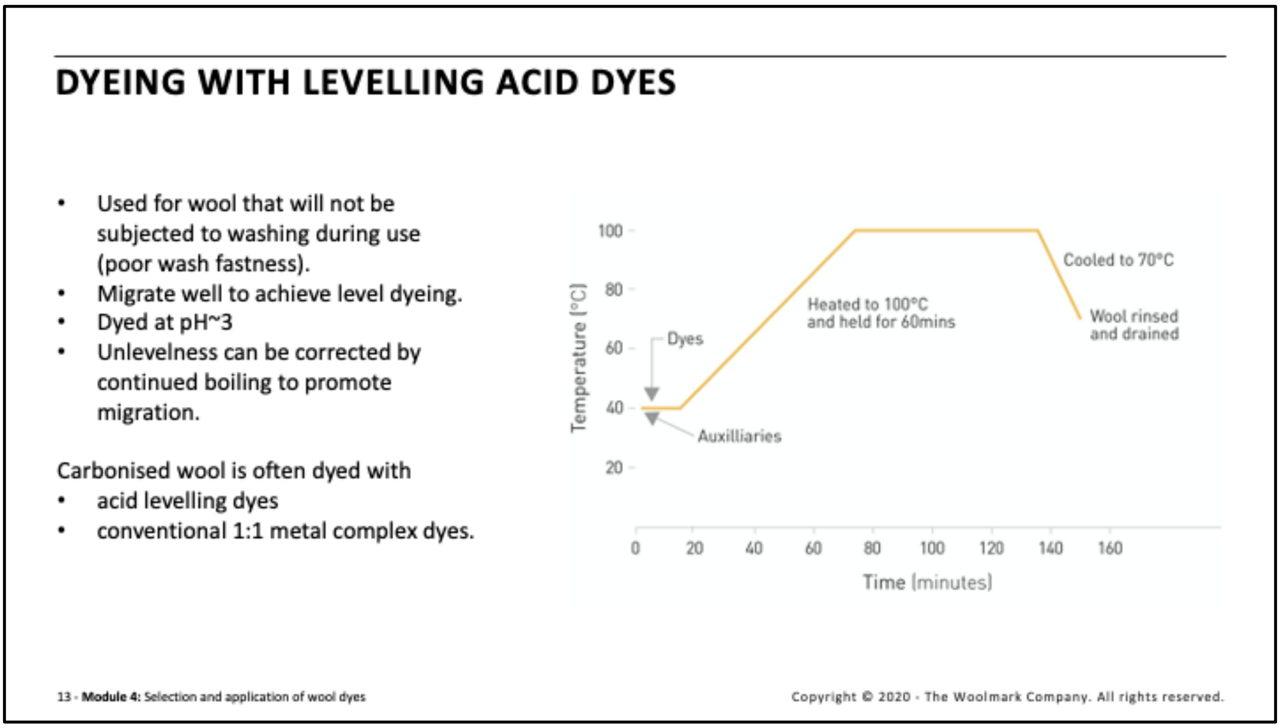
EXPLAIN THAT in overflow and jet machines used for fabric dyeing, foaming can lead to pump cavitation and floating of the fabric (risking unlevel dyeing). Anti-foam agents can build up on the dyeing vessel walls and/or lead to spotting on the fabric. It is much safer to use non- or low-foaming auxiliaries.

Lubricants

INDICATE THAT lubricants are used to ensure even running of fabric in piece dyeing. They reduce fibre-to-fibre and fibre-to-metal friction to allow easier movement of the fabric in piece dyeing machines.

Dispersants

POINT OUT that dispersants are used for disperse dyes to prevent the dyestuff agglomerating on the surface of the fibre in blend dyeing.



INDICATE THAT levelling acid dyes are normally applied at around pH=3 with formic or sulphuric acid.

The rate of temperature rise can be relatively high when using these dyes because they level (migrate) well at the boil.

POINT OUT that in the case of a dyeing in which the initial exhaustion was unlevel, the dyeing can normally be rectified by extending the time at the boil.

Method

- The bath is set at 40ºC generally with 10% sodium sulphate and a levelling agent.
- The dye is added and the bath heated to the boil at a rate of 1–1.5ºC/min and held for 60mins.
- The bath is cooled to 70ºC and the wool is rinsed and removed.

Usage
Levelling acid dyes may be used for wool that will not be subjected to washing in consumer use.

EXPLAIN THAT the advantage of these dyes is their ability to migrate and provide level dyeing with good seam penetration on garments that can be improved by extending the dyeing time at the boil.

NOTE THAT when applied to non-shrink resist garments dyeing times must not be extended too much, otherwise excessive felting shrinkage may occur.

Carbonised wool is often dyed with

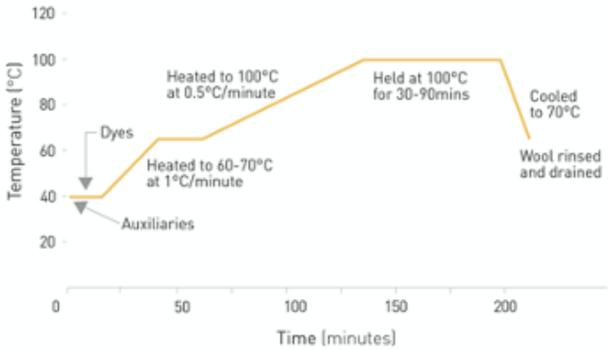
- acid levelling dyes
- conventional 1:1 metal complex dyes.

DYEING WITH MILLING ACID DYES

Milling (Class 1 or Class 2) dyes have lower migration that acid levelling dyes:

- It is essential levelness is achieved during dye exhaustion.
- Dyed at pH~4–4.5 (pH=6–8)
- Holding temperature at 60–70ºC to ensure even exhaustion.
- Medium wash fastness.

Felt-resist treated fibre starts at 30ºC.



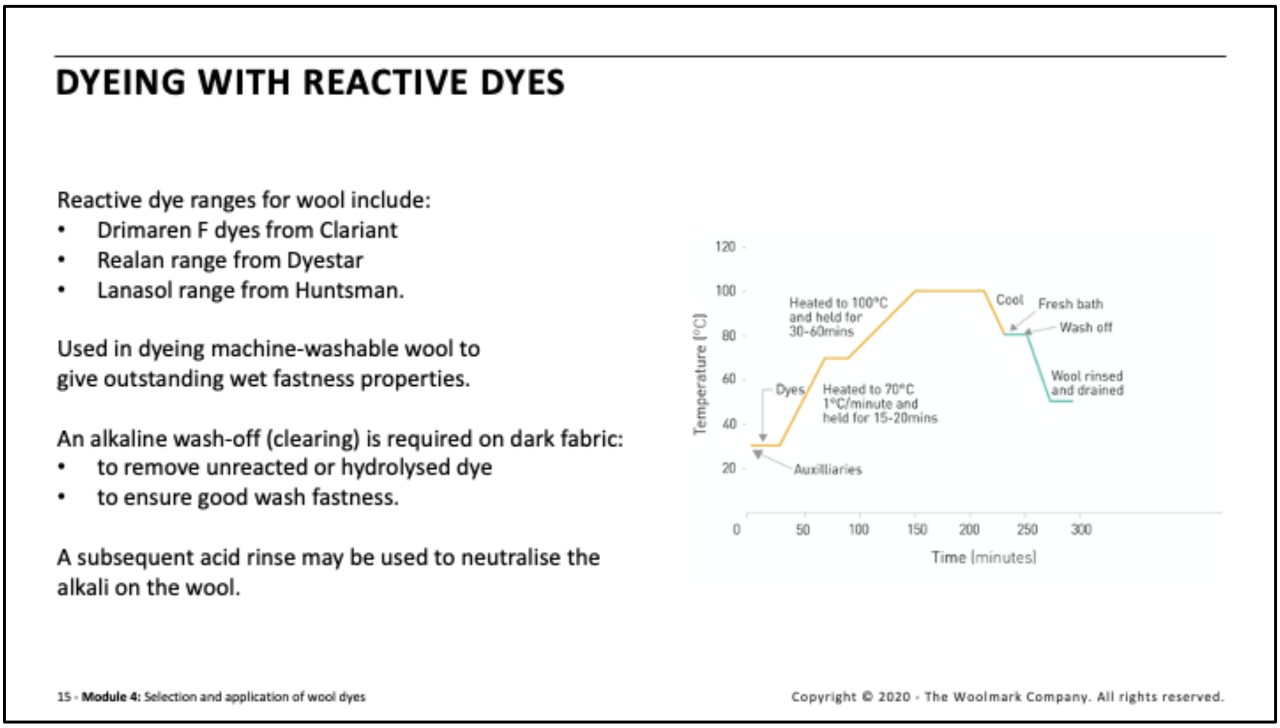
14 - **Module 4:** Selection and application of wool dyes

INDICATE THAT milling (Class 1) or fast acid (Class 2) dyes have poorer migration than the acid levelling dyes.

EXPLAIN THAT it is essential that levelness is achieved before the dyes are 'fixed' onto the fibre.

Method

- The bath is set with 10% sodium sulphate.
- A levelling agent is included.
- Acetic acid and acetate are used to adjust the pH to 4–4.5 (or higher for the Class 2 dyes as required).
- The temperature is increased at less than 1ºC/min to 60–70ºC to ensure even exhaustion throughout the substrate. Milling dyes normally exhibit an increase in dyebath exhaustion rate between 65°C and 75°C.
- A holding period in the time/temperature profile is recommended to allow the dyes increased time for migration.
    - The holding temperature should therefore be below that at which exhaustion increases and should be determined in the laboratory.
- The temperature is increased to boiling point for 30–90mins, depending on depth of shade required.
- The bath is cooled to about 70ºC and the wool is rinsed and removed.



EXPLAIN THAT early reactive dyes gave considerable unlevelness and were limited to fibre dyeing. However, the use of amphoteric levelling agents (e.g. Albegal B) has allowed the successful use of reactive dyes on wool yarn, fabric and garments.

INDICATE THAT when these dyes are applied, exhaustion and reaction rates must be balanced to avoid unlevelness.

Method

- The dyebath is set at pH=7.0 with ammonium acetate (pH=5 for some reactive dye types).
- Dyeing is started at a lower temperature (30°C) to ensure even uptake of the dye.
- A temperature rise of 1°C/min is used with a holding period at 70°C for 15–20mins. Fixation at this temperature is low and dye migration can therefore occur.
- The temperature is raised to the boil for 30–60mins.
- The bath is cooled and a fresh bath is made up at pH=8.0–8.5. The substrate is washed off for 15–20min at 80°C to remove unfixed dyes (necessary for darker shades).
- The dyed substrate is rinsed and acidified with 1% acetic acid in the rinse bath.

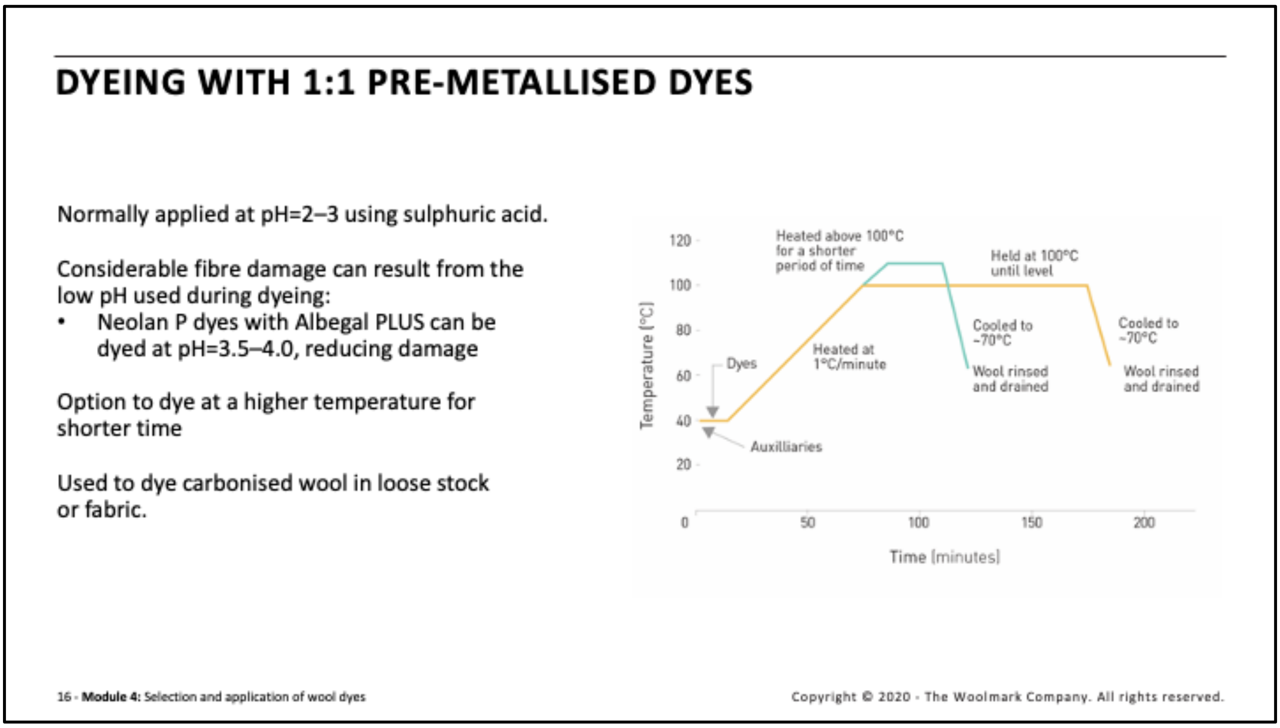
POINT OUT that levelling agents are used with reactive dyes to promote exhaustion, fibre and surface levelness, and assist the penetration of the dyes into the wool fibre.

NOTE THAT with pale and medium shades on yarn and piece goods, 5–10% sodium sulphate can be used to promote surface levelness by slowing down the rate of dye uptake.
At liquor ratios from 8:1 to 30:1, an auxiliary such as 1–2% Albegal B is added, depending on the shade depth desired. Albegal B is amphoteric and has affinity for both dye and fibre.

For darker shades, the higher amount of Albegal B is recommended in order to improve exhaustion.

Usage

NOTE THAT reactive dyes are commonly used for machine-washable wool because of their superior wet fastness.



INDICATE THAT 1:1 pre-metallised dyes are normally dyed at very low pH levels (in the order of pH 2.0–3.0) using sulphuric acid.

Dyeing at such low pH can damage the wool. The Neolan P dyes, which are applied at pH=3.5–4.0, were introduced to limit fibre damage.

Method

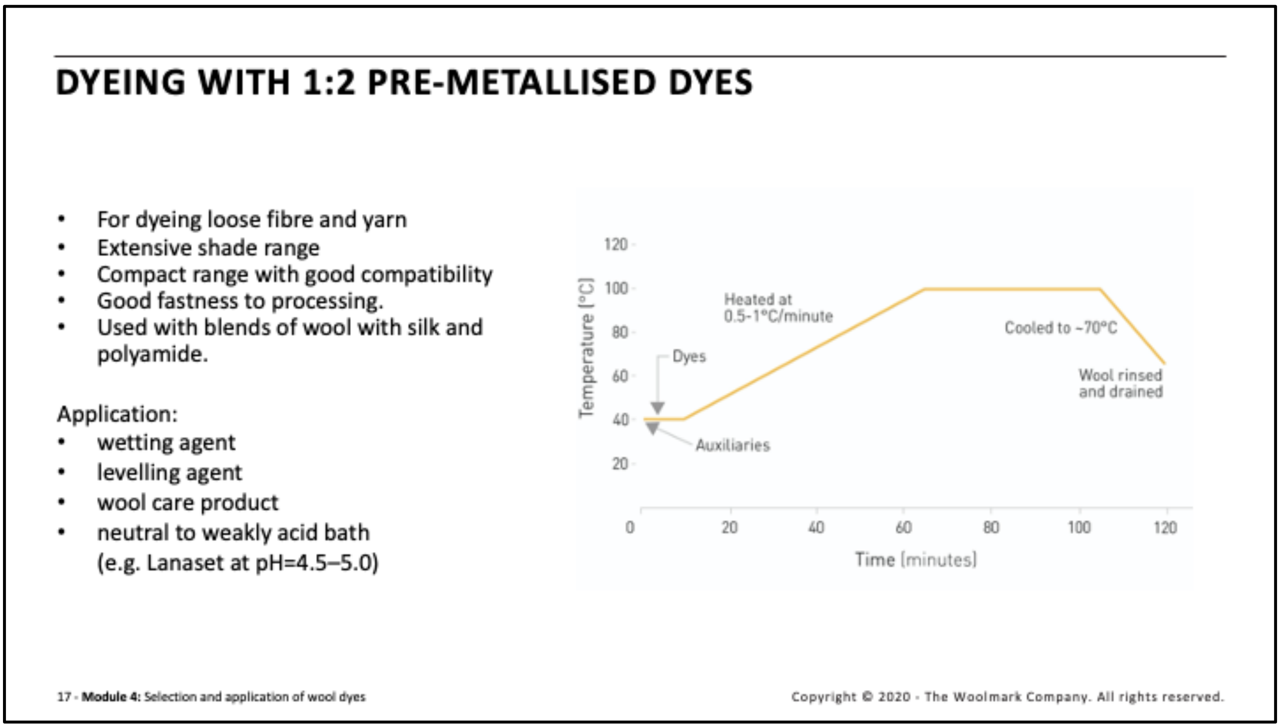
- The bath is set with 6–10% sodium sulphate (for piece goods and yarn)
- An amphoteric levelling agent is sometimes used. Albegal PLUS (2–3% omf) complexes with the dye to allow easier exhaustion.
- An antifoam may be used for overflow fabric machines.

EXPLAIN THAT with 1:1 metal complex dyes the rate of temperature rise can be relatively high, because these dyes level (migrate) well at the boil. An unlevel dyeing can normally be rectified by extending the time at the boil.

POINT OUT that as indicated in the illustration on the slide, 1:1 pre-metallised dyes can also be dyed at temperatures above 100°C for a shorter time.

Usage

1:1 Pre-metallised dyes are commonly used to dye carbonised wool in loose stock or fabric.



INDICATE THAT 1:2 pre-metallised dyes give reasonable levelling properties and fastness, allowing use in fibre or yarn dyeing.

EXPLAIN THAT the time/temperature profile for fibre dyeing depends greatly on:

- the characteristics of the dyeing machine
- the density and uniformity of the fibre load.

Method

- The bath is set with:
  - a wetting agent (e.g. Albegal FFA)
  - an anionic or amphoteric levelling agent (e.g. Albegal SET)
  - a wool protective agent (e.g. Miralan Q)
  - a neutral to weakly acid bath (pH ~5) using acetic acid (i.e. acetate)
- After adding the dyes the temperature is increased at a rate of ~1°C/min.
- A 15–20min hold at 75°C is recommended for yarns, but is not necessary when dyeing loose fibre.
- Medium depth (1.0–1.5%) shades of 1:2 metal complex dyes need at least 20 minutes at 98–100°C to achieve acceptable penetration of wool and avoid 'ring' dyeing.
- A minimum dyeing time of 30 minutes is recommended and longer for heavy shade depths.

Sulphonated pre-metallised dyes

INDICATE THAT typically these dyes use similar additives and are applied at pH~4–6.5 acetic acid/acetate buffer or ammonium sulphate.

Usage

NOTE THAT 1:2 pre-metallised dyes are commonly used on fibre and yarn and can be used for blends of wool with silk and polyamide due to their compatibility with a range of fibre types.

DYEING WITH CHROME DYES

A formerly popular method for dark shades, which can be applied to wool at any stage of processing (loose stock, top, yarn or fabric).

Three methods can be used to apply the dye:
- pre-chrome
- after-chrome
- simultaneous (meta-chrome)

The after-chrome method is preferred as it:
- creates less damage to the fibre than the alternative methods
- has better wash fastness.

18 - **Module 4:** Selection and application of wool dyes

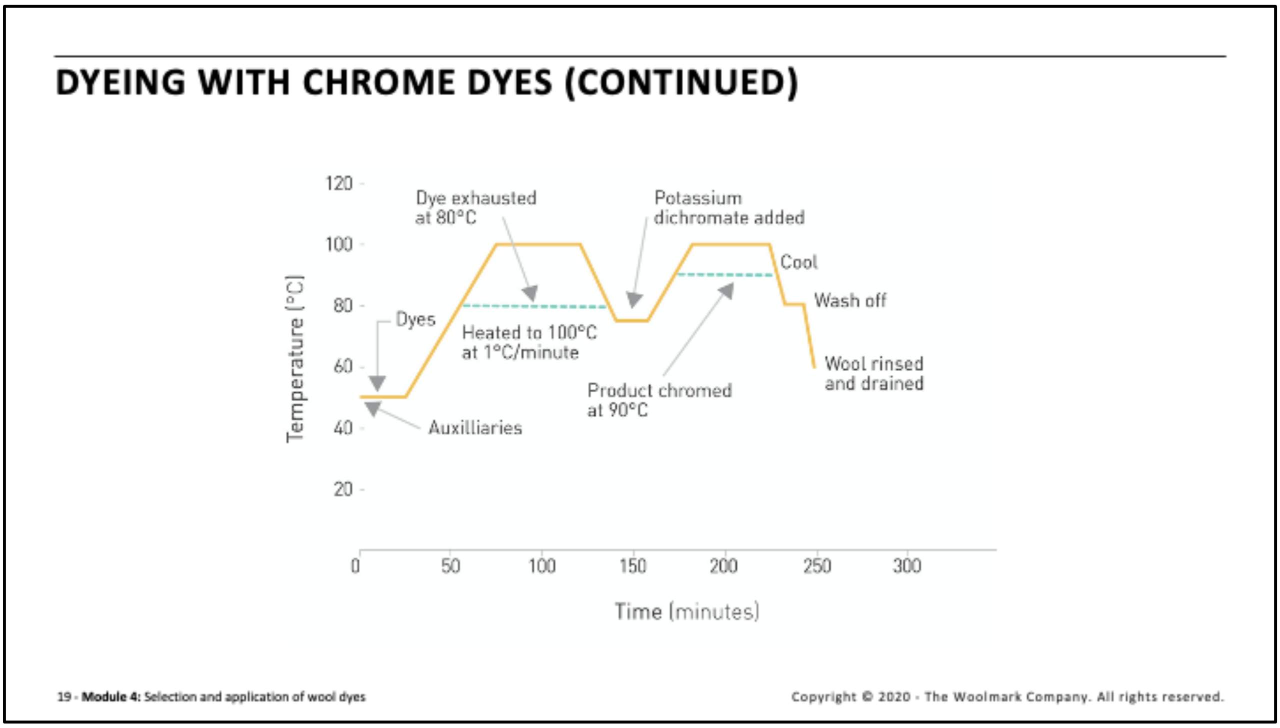
INDICATE THAT chrome dyes remain a popular method for producing dark shades, which can be applied to wool at any stage of processing (loose stock, top, yarn or fabric).

Chrome dyes are applied from a weakly acid bath and are subsequently mordanted to form a stable complex in the fibre with trivalent chromium.

NOTE THAT the properties of chrome dyes include:
- good levelling and penetration
- good to very good light fastness.

Methods
Three methods can be used to apply a chrome dye:
- Pre-chrome — In the pre-chroming process the wool is first mordanted with potassium dichromate and acid, after which it is dyed in a fresh bath with selected dyes.
- After-chrome — In the after-chroming process the wool is first dyed then mordanted with potassium dichromate and acid.
- Meta-chrome or simultaneous — In this ‘one-bath’ process the dyebath is set with selected chrome dyes, potassium dichromate and ammonium sulphate.

MENTION THAT the most widely-used dyeing method is the after-chroming process, which also gives the best fastness properties. This method gives excellent wet fastness, even with dark shades. The method for after-chrome dyeing is discussed on the next slide.



INDICATE THAT after-chrome dyeing is used for a number of wool product types including:

- loose fibre
- yarn and piece goods for ladies' and men's outerwear
- uniforms
- knitting yarns
- floor coverings.

Method

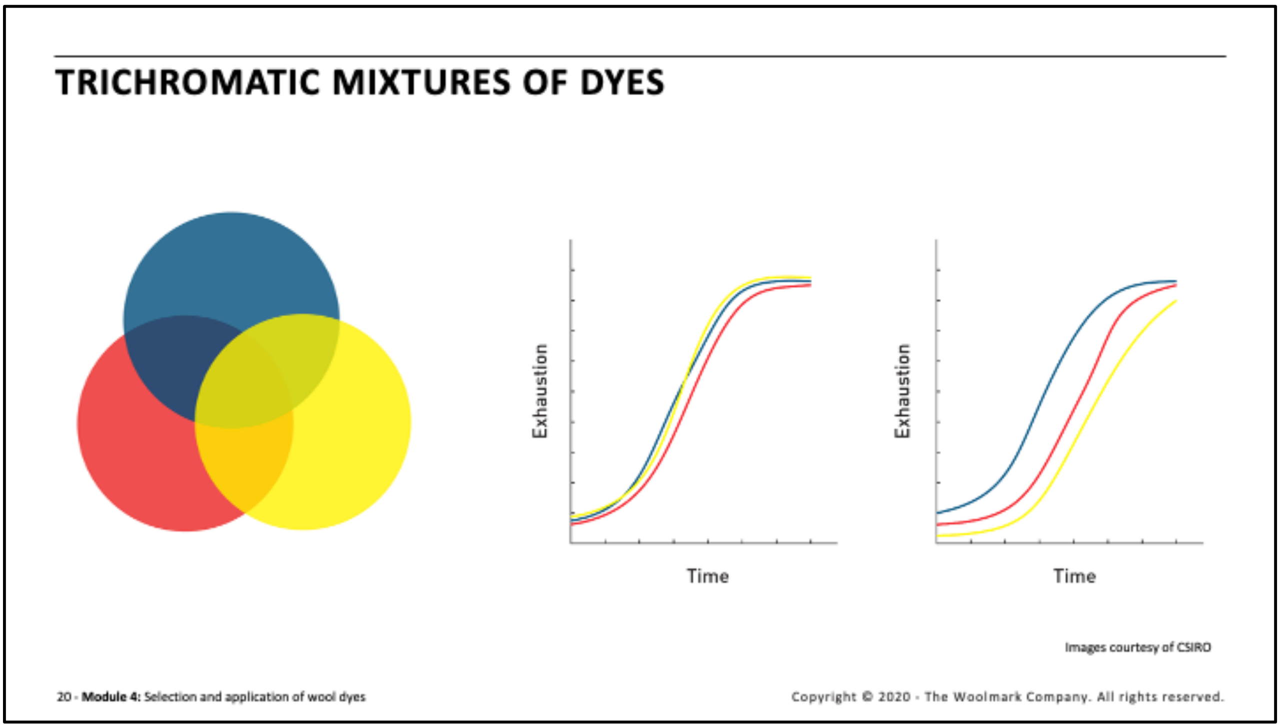
There are a number of methods for after-chrome dyeing of wool

- at the boil
- below the boil.

POINT OUT that the method for after-chrome dyeing at the boil is illustrated on the slide:

- The bath is set with
    - 1–2% acetic acid (pH~5)
    - 5% sodium sulphate
    - a levelling agent.
- The bath is heated at 1°C/min to the boil.
- After 30mins formic acid (pH~4) is added to complete exhaustion.
- The bath is cooled to 75°C and potassium dichromate (0.5–1.5%) added
- The bath is reheated to the boil for 30–45mins.
- The bath is cooled and the wool washed off with ammonia at pH=8 to remove any yellow-staining impurities.
- The wool is rinsed and acidified.

NOTE THAT in some processes the dye is exhausted at 80°C and the product chromed at 90°C (indicated by the dotted lines on the slide).



EXPLAIN THAT many colours are achieved using a mixture of dyes (often yellow, red and blue) rather than a single dye.

Trichromatic dye ranges to achieve a number of colours have been developed in a number of dye types.

INDICATE THAT compatibility between the dye types is required to ensure:

- they exhaust at similar rates (see diagram showing dyes with different rates of exhaustion)
- they do not highlight skittery effects in the fibres.

Trichromatic dye ranges

Acid dyes are available in Sandolan E (Clariant) as well as other ranges.

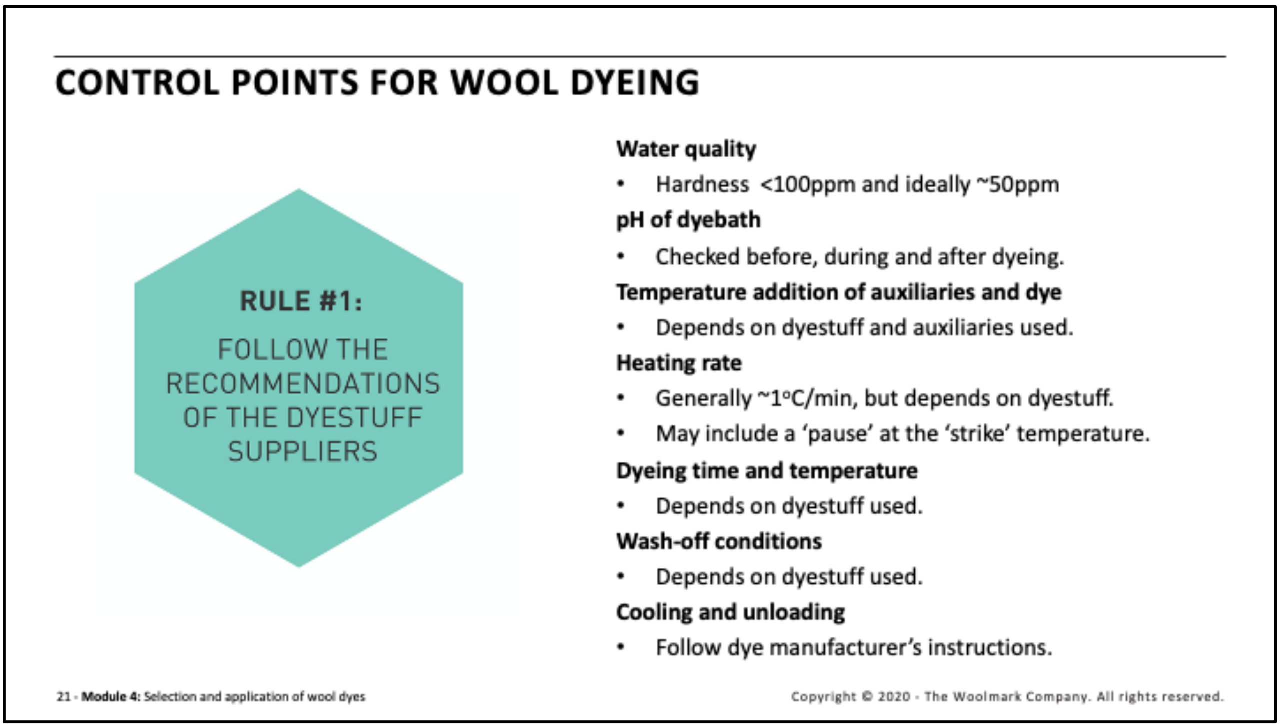
1:1 pre-metallised dyes are available in Neolan P (Huntsman) ranges.

1:2 pre-metallised dyes are available in Lanaset (Huntsman) range.

MENTION THAT reactive dyes are available in:

- LANASOL Yellow 4G, Red 6G and Blue 3G. For darker shades, LANASOL Orange RG or Scarlet 3G can be used as yellow and red components respectively. The Lanasol CE dyes (Huntsman) offer a similar range.

NOTE THAT modern commercial dye ranges are no longer limited to a single dye type. The Lanaset range contains some dyes that are 1:2 pre-metallised dyes and others are reactive dyes. Dyes are chosen that are applied under similar conditions and are suitable for similar applications.



INDICATE THAT the points of control for the dyer and the points at which quality control procedures must be used are:

Water quality
- Hardness <100ppm and ideally ~50ppm

pH of dyebath
- Check before, during and after dyeing.
- pH meter should be used rather than pH papers.

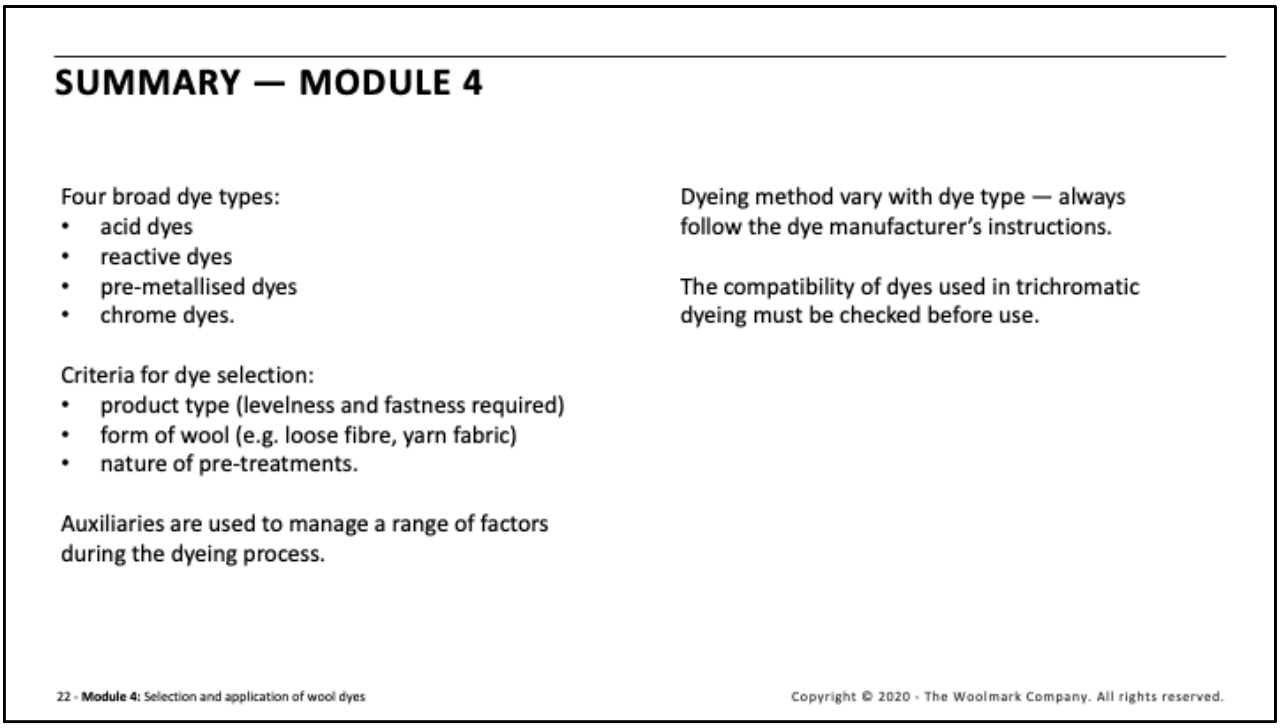
Temperature of addition of auxiliaries and dyes
- Depends on dyestuff and auxiliaries used.

Heating rate
- Generally~1°C/min, but depends on dyestuff.
- May include a 'pause' at the 'strike'. temperature

Dyeing time and temperature
- Depends on dyestuff used.

Wash-off conditions
- Depends on dyestuff used.

Cooling and unloading
- Always follow the recommendations of the dyestuff suppliers.



REITERATE THAT there four broad types of dyes used for dyeing wool and wool blends:

- acid dyes:
    - acid levelling dyes
    - acid milling dyes (Class 1)
    - acid milling dyes (Class 2).
- reactive dyes
- pre-metallised dyes
    - 1:1 pre-metallised dyes
    - 1:2 pre-metallised dyes
    - sulphonated 1:2 pre-metallised dyes
- chrome dyes.

REMIND participants that the criteria for selecting wool dyes include:

- the product with which they will be used and the levelness and fastness required
- the form of the wool in dyeing (e.g. loose fibre, yarn, fabric)
- the nature of any pre-treatments.

REVIEW a range of auxiliary products is used in wool dyeing to:

- control pH
- manage levelness
- ensure sufficient wetting
- control brightness
- protect fibres against damage
- improve colour fastness
- remove dye from the fibre
- remove metal ions from the dyebath
- prevent foam production during dyeing
- control friction
- improve dispersion.

REMIND participants that although methods of dyeing vary slightly with each dye type, the key processes involve:

- setting and managing the temperature of the dyebath through out the process
- adding the dye and auxiliaries
- managing the rate of temperature rise and time of boil
- the nature of any after-treatments.

REVIEW the fact that trichromatic dyes can be used to achieve an extensive range of colours. Ensuring compatibility of the dyestuffs is critical.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants of the time and location for the next lecture — *Module 5 Dyeing at various stages in wool processing* — and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

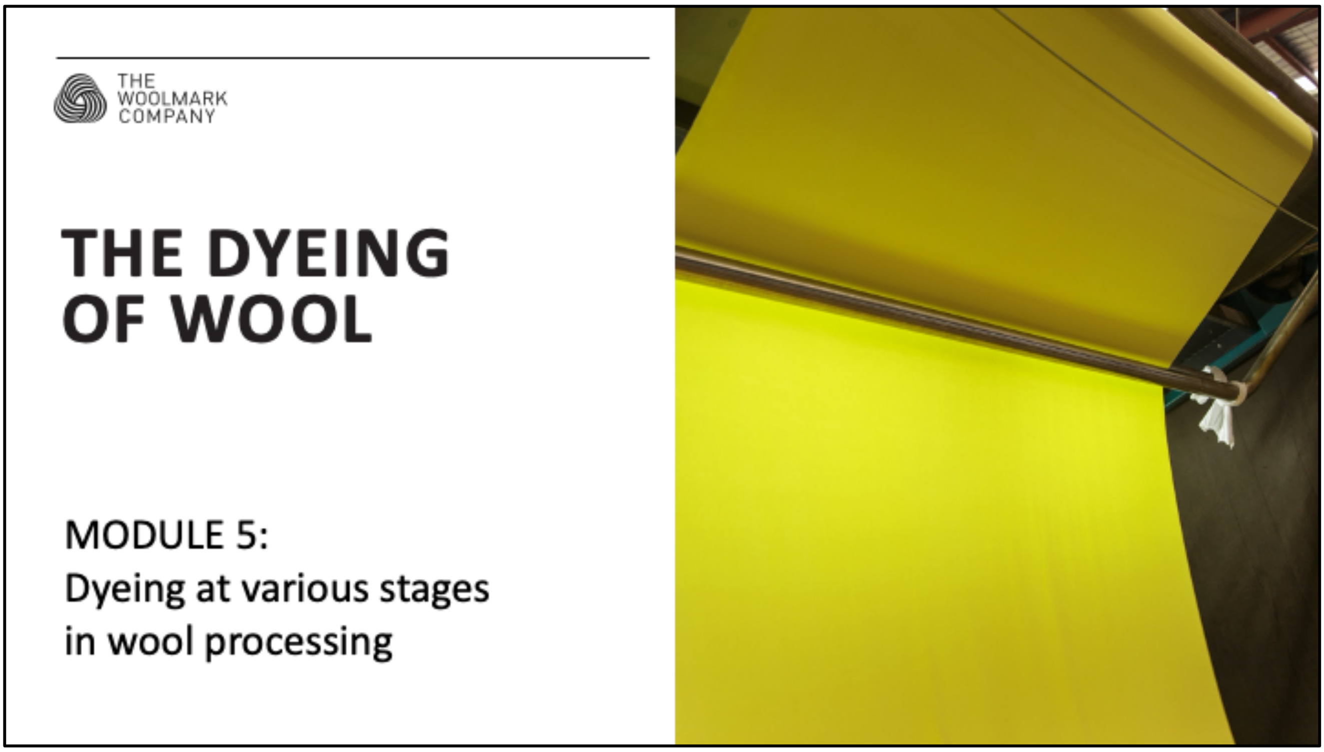
Participants can register with and explore the Woolmark Learning Centre here:
www.woolmarklearningcentre.com

DYEING AT VARIOUS STAGES IN WOOL PROCESSING

RESOURCES — MODULE 5: DYEING AT VARIOUS STAGES IN WOOL PROCESSING

Contained in *The dyeing of wool* Demonstration kit you will find the following resources for use as you deliver **Module 5: Dyeing at various stages in wool processing**:

- dyed and undyed loose wool
- dyed and undyed top
- dyed and undyed yarn in hank
- dyed and undyed yarn in package
- dyed and undyed knitted fabric
- dyed and undyed woven fabric
- dyed and undyed garment



WELCOME participants to Module 5 of the Woolmark Wool Science, Technology and Design Education Program — *The dyeing of wool — Dyeing at various stages in wool processing*

EXPLAIN THAT this module covers the preparation, processes and machinery involved with dyeing wool at various stages throughout the wool processing chain (loose stock, top, yarn, fabric and garment).

INDICATE THAT the advantages and disadvantages of each process will be explored including, the challenges and issues facing dyers and the quality control measures put in place to ensure an optimal dyeing outcome.

INFORM participants that by the end of this module they will be able to:

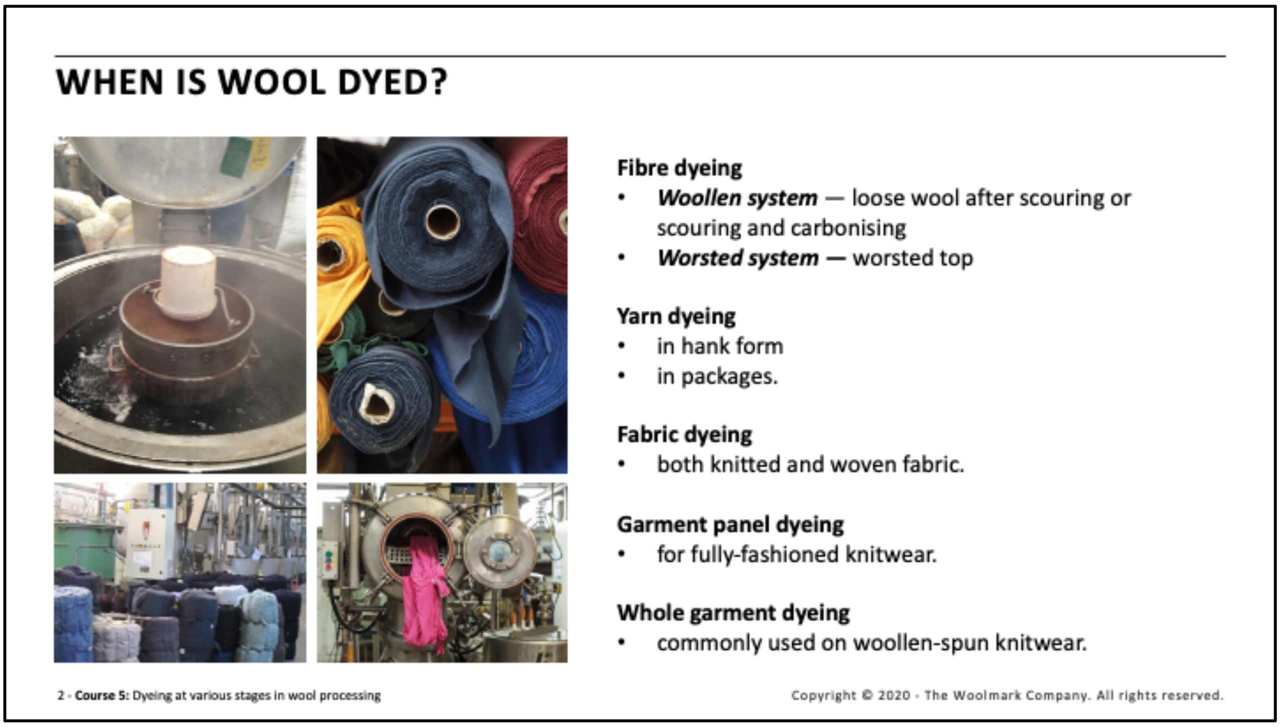
- describe the preparation, processes and machinery used to dye wool at each stage of the wool processing stage
- describe the advantages and disadvantages associated with dyeing at each stage of the wool processing stage
- outline the key challenges faced when dyeing wool and the quality control measures employed.

RESOURCES REQUIRED FOR THIS MODULE

- dyed and undyed loose wool
- dyed and undyed top
- dyed and undyed yarn in hank
- dyed and undyed yarn in package
- dyed and undyed knitted fabric
- dyed and undyed woven fabric
- dyed and undyed garment

NOTE TO FACILITATOR:

This module will take approximately two hours to cover. A suitable break point would be after Slide 34 Package drying, *immediately before Slide 35* Fabric or piece dyeing



INDICATE THAT wool can be dyed at various stages through the wool processing chain.

Scoured or scoured and carbonised loose fibre for the woollen system — allows blending to form multi-coloured yarns, frequently used in woollen garments.

Tops for the worsted system — if the scoured fibre for the worsted system is dyed, it is most commonly dyed after the transformation to top form has taken place (dyeing is rarely carried out on loose fibre for worsted processing). Coloured fibre waste that would be created during top-making of wool dyed after scouring would be much less valuable than undyed top. Top dyeing is the most common form of dyeing in worsted processing.

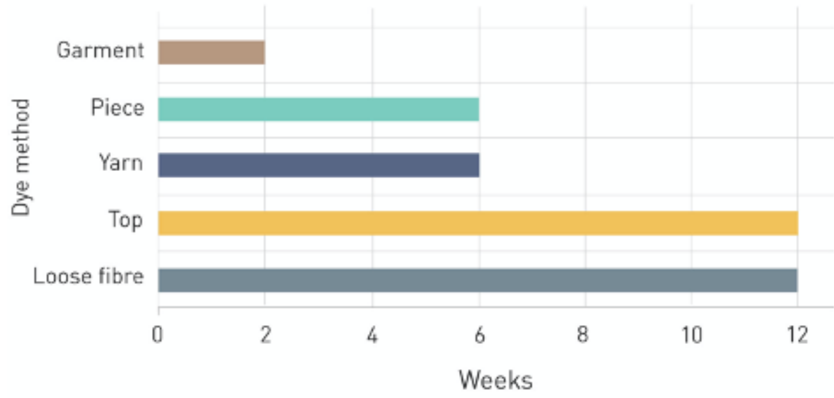
Yarn — can be dyed as hanks or packages. These terms will be clarified later in this module.

Fabric — can be dyed as knitted or woven fabric. Fabric dyeing is often called 'piece dyeing'.

Garment panels — the panels of garments made in fully-fashioned knitting machines to be subsequently linked to form fully-fashioned garments can be dyed in panel form before being constructed into garments.

Completed garments — dyeing can also be carried out as complete wool garments (most commonly woollen-spun knitwear).

THE CONCEPT OF LEAD TIME



3 - **Course 5:** Dyeing at various stages in wool processing

NOTE THAT lead time is the time that normally elapses between the decision on the processing of a lot of wool and its appearance as a product on the shelves of a retailer.

MENTION THAT in the context of dyeing, it is the time between the decision on colour and dyeing of the wool and the product being delivered to the retailer.

EXPLAIN THAT lead time is important in all stages of manufacturing. The longer the lead time the more stock that is carried by the processing chain and the less flexibly the application of colour can respond to fashion changes.

For fibre dyeing — The dyed fibre in loose (woollen) or top (worsted) form must be processed to yarn then formed into fabric and eventually into the final product. This normally typically takes around 12 weeks.

For yarn dyeing — The dyed yarn can be formed into fabric or knitted directly into garments so the lead time is shorter, typically around six weeks.

For fabric (piece) dyeing — The dyed fabric must be dry finished and manufactured into garments, so the lead time is typically around six weeks.

Garment dyeing — has the shortest lead time; as low as two weeks. As such garment dyeing provides the best opportunity for responding to rapid changes in fashion cycles. Garment pieces produced by fully-fashioned knitting machines must firstly be linked to form the final garment so have a slightly longer lead time than other garment types.

FIBRE DYEING — LOOSE STOCK

Benefits:
- Uniform shade across large lots of fibre
- Allows maximum wet fastness
- Achieve mélange shades and multi-coloured yarns
- Minimises dyeing costs
- Allows separate fibre dyeing for blended product

Disadvantages:
- Long lead times (>3 months)
- Fibre damage during dyeing (lower carding and spinning efficiencies)
- Dyes must have good wet fastness
- Higher risk of contamination.

4 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT dyeing fibre as loose stock is used to:

- achieve large lots of uniform shade (slight unlevelness or differences between batches can be eliminated in subsequent blending during carding or gilling)
- achieve maximum wet colour fastness with good shade uniformity
- achieve mélange shades or multi-coloured 'heather' yarns
- minimise dyeing costs
- colour for blends with other fibre types, where different dyes and methods must be used for the differing fibres and when the cross-staining with different dye types is possible.

POINT OUT that there are some disadvantages to fibre dyeing, which are relevant to dyeing and subsequent processing including:

Long lead times — The shade and quantity to be dyed must be selected at an early stage of processing (typically at least six months prior to retail) leaving little flexibility for changes to be made once the process is underway.

Lower tensile strength — Dyed wool fibres have lower tensile strength than their undyed counterparts and therefore will process less efficiently.

Wet fastness — Dyes must be used that are fast to any wet process to which the fibre will subsequently be subjected (e.g. scouring, milling, crabbing), limiting the dye options.

Colour contamination — The risk of contamination when dyeing loose stock is relatively high compared with dyeing at other stages throughout the wool processing route.

Coloured waste — The quantity of fibre dyed to meet specific orders is often slightly more than necessary, to allow for 'waste' (i.e. noil etc) during processing. Unless the excess dyed fibre can be re-used it is of low value and poses a cost to the processor.

DYE SELECTION FOR FIBRE DYEING

PRODUCT REQUIREMENTS	DYE CLASS	COMMENTS
Knitwear — wovens (dry clean only)	1:2 metal complex Milling Half-milling (pale shades)	Applicable to normal processing
Knitwear — wovens (hand washable)	1:2 metal complex Milling Reactive	Dyes need selection if oxidative felt-resist is to be applied
Knitwear (machine washable)	Selected 1:2 metal complex Selected milling Reactive Chrome	Dyes need selection if oxidative felt-resist processes are used
Woven	Selected milling Reactive Chrome	Require fastness to scouring and milling (possibly crabbing)

5 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT there are two main forms of fibre dyeing:

- loose fibre dyeing (woollen system)
- top dyeing (worsted system).

When selecting appropriate dye types for loose fibre or top dyeing, 1:2 metal complex dyes, particularly mono- and disulphonated types, form the backbone of wool fibre dyeing recipes because:

- they are cost-effective
- they are relatively easy to apply.

NOTE THAT however, many do not give machine-washable fastness and the shade range of metal complex dyes is limited.

INDICATE THAT the relative dullness of metal complex dyes has an advantage — recipes are less sensitive to small changes in dye concentration than those based on brighter components.

Where bright shades are required milling dyes, or possibly reactive dyes are used.

POINT OUT that optimised dye ranges have been developed, which can be applied with a standard procedure for all shades and dye combinations. These include:

- Lanasan (Clariant)
- Supralan (Dyestar)
- Lanaset (Huntsman).

Other manufacturers may supply similar products.

MENTION THAT chrome dyes are also used for dark shades requiring high wet fastness. This type of dye is commonly used to dye top dark colours.

REFER participants to the table on the slide, which outlines the options available for fibre dyeing across a range of product requirements.

MACHINERY FOR FIBRE DYEING — LOOSE STOCK

Many loose stock dyeing machines are commercially available.

All rely on circulating dye liquor through a stationary pack of fibre.

All require uniform packing to ensure levelness of liquor flow and shade.

It is recommended that:

- wool is loaded automatically
- the pack is pneumatically pressed or mechanically stamped.

It is beneficial to wet the fibre as it is loaded.

6 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT machinery for batch dyeing loose stock wool fibre varies widely. All types of loose stock dyeing machinery rely on circulating dye liquor through a stationary pack of fibre.

INDICATE THAT all require uniform packing to avoid 'channelling' (uneven flow of the dye liquor through the fibre mass) and ensure levelness of liquor flow and shade. It is recommended the wool be loaded automatically and the mass of fibre pneumatically pressed or mechanically stamped.

EXPLAIN THAT it is beneficial to wet the fibre as it is loaded, particularly if it is automatically stamped. Automatic stamping is recommended, because of the greater uniformity of packing it delivers. Stamping devices are relatively inexpensive and widely available. Pneumatic press packing is an alternative to stamper loading.

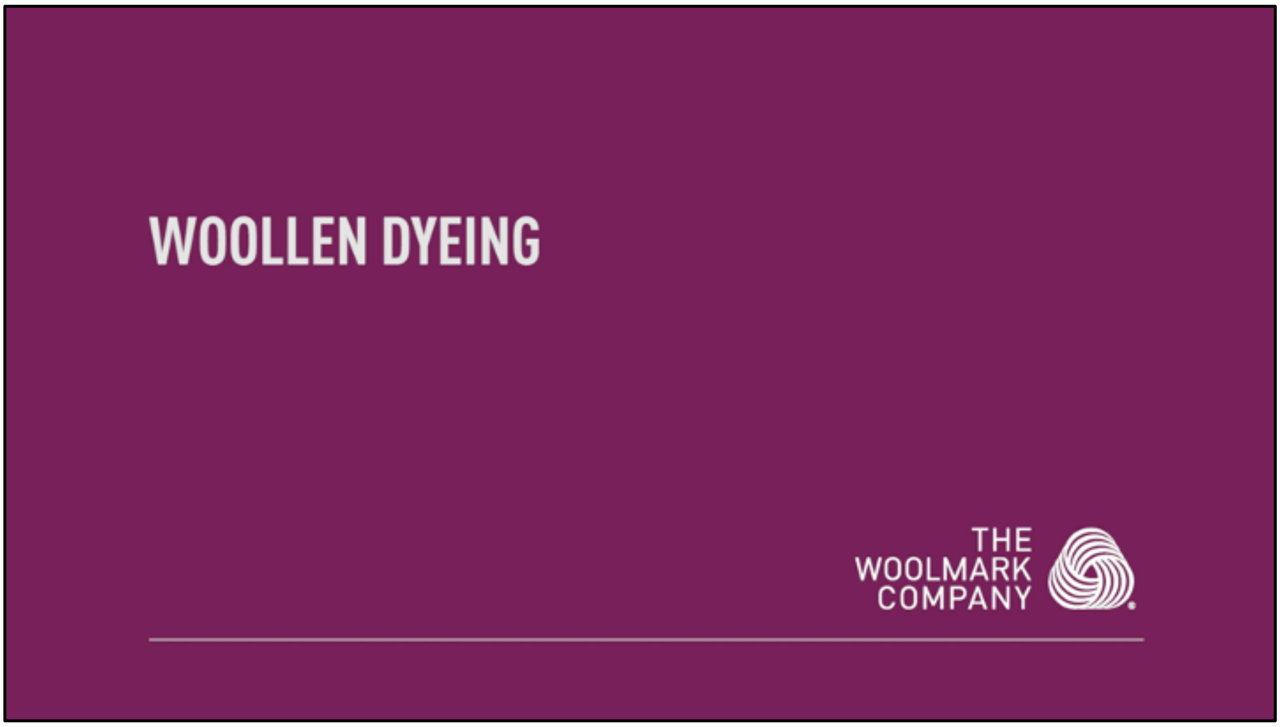
Water consumption can be minimised by recycling the water used during packing.

A typical density for loose fibre is 250g/l, although this may be increased for some radial flow machines.

NOTE THAT most modern loose stock dyeing machinery is sealed and can operate under pressure should dyeing at high temperatures (>100°C) be required for synthetic fibres.

POINT OUT that pear-shaped machines have impeller circulation rather than pumped-liquor circulation.

Conical pan machines, which operate with constant bottom-to-top liquor flow, can be manually loaded.



LOOSE DYEING
The following Woolmark Company video provides an overview of the loose fibre dyeing process and also shows the first stage of drying (mechanical – spin dry).

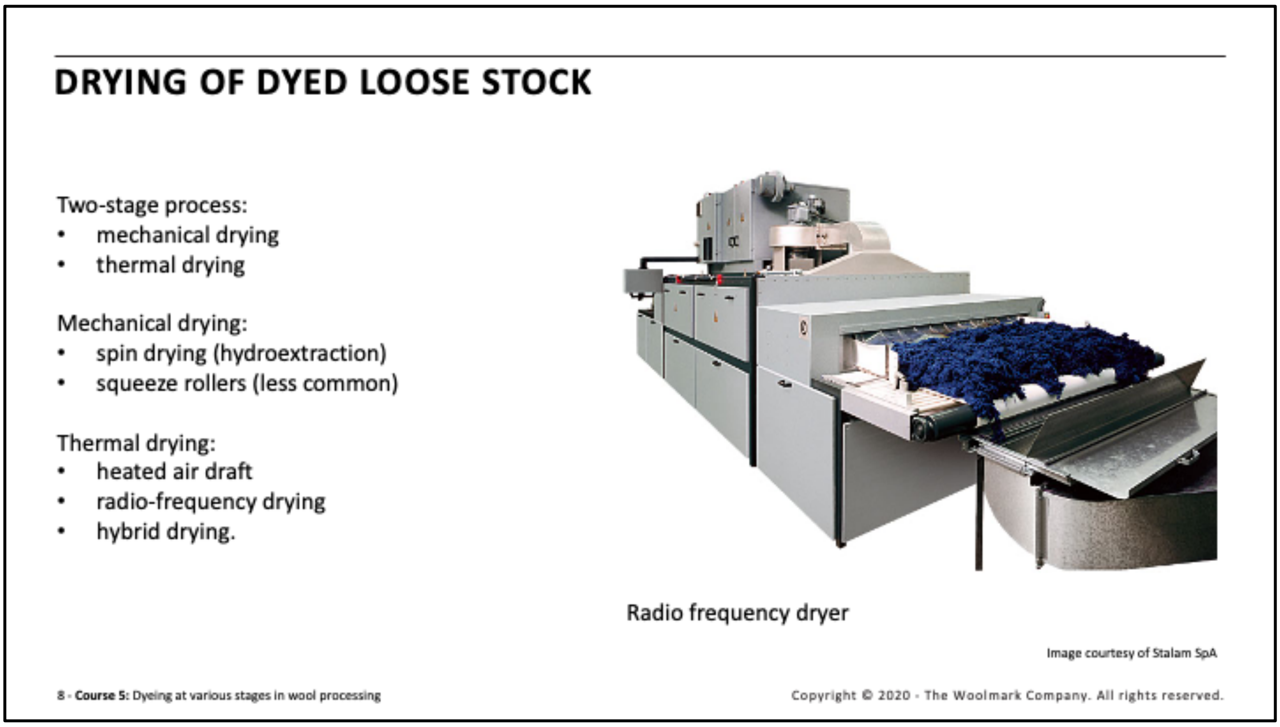
PLAY *video (3:10 minutes)*

NOTE *THE key points as the video is playing:*

- *the need to pack the fibre evenly in the dyeing machine to avoid channelling and uneven dyeing*
- *the mechanical removal of excess water from the fibre after dyeing.*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond.*



INDICATE THAT wet wool is difficult to process — after the loose stock has been dyed the wool must be dried in preparation for the next stage of processing.

NOTE THAT drying of the dyed fibre involves two stages:

- mechanical drying
- thermal drying.

EXPLAIN THAT mechanical drying is less expensive than thermal drying so it is important to remove as much water as possible during this stage.

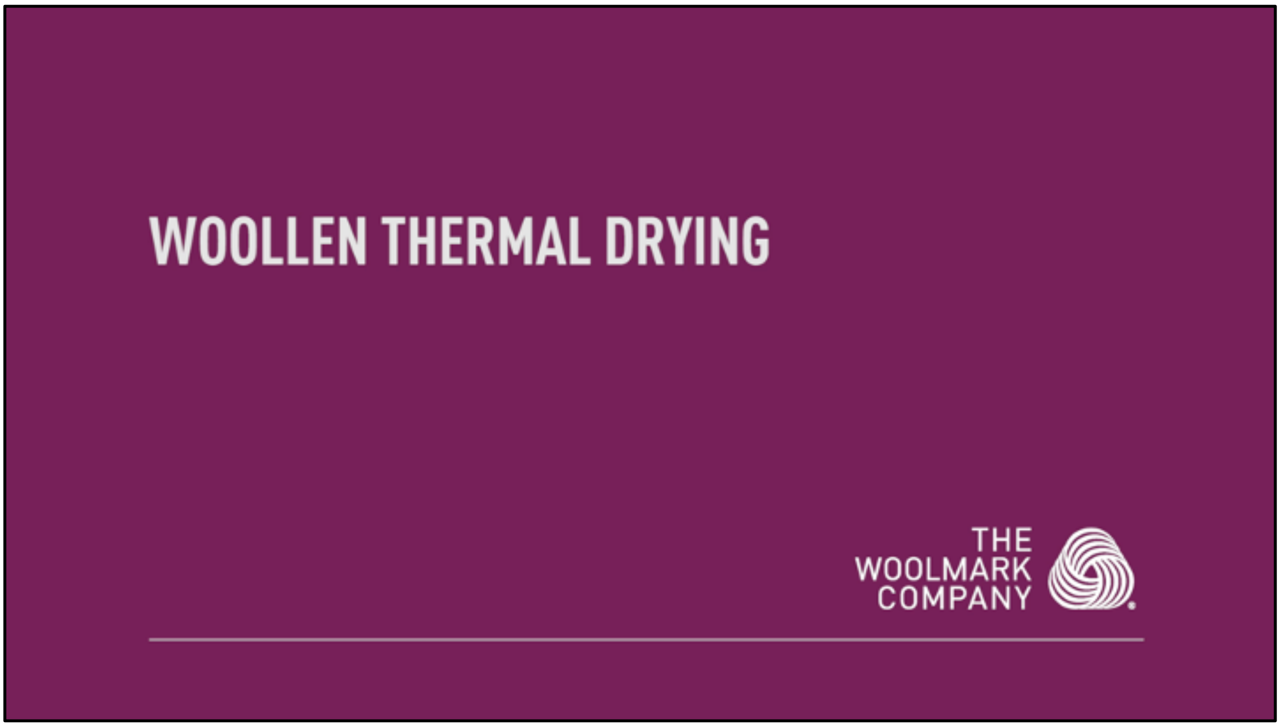
Mechanical drying

During mechanical drying the loose fibre is generally spin dried. Squeeze rollers can be used, but are not usually as efficient as spin drying.

Thermal drying

Three types of thermal dryers are used:

- Hot air drying uses a similar in action to the dryer used after raw wool scouring. Hot air is forced through a continuously moving layer of wool. Channelling of the hot air can lead to wet patches remaining in the wool.
- Radio-frequency drying — RF dryers operate like a microwave oven — the water on the wool is heated and evaporated by radiation. Most RF dryers operate in a continuous manner. Some RF dryers can generate high temperatures in the middle of a deep layer of loose fibre. If the temperature becomes too high the fibre can yellow.
- Hybrid dryers combine RF with forced airflow.



DRYING DYED LOOSE STOCK
The following Woolmark Company video provides an overview of the fibre drying process.

***PLAY** video (2:29 minutes)*

There are two stages in the drying of wool dyed as loose fibre – mechanical (spinning) and thermal drying. The second stage is illustrated in this video.

***AS** the video play note the even spread of fibre on the belt to avoid channelling of the air and uneven drying.*

***ASK** participants if they have any questions or comments regarding the video content.*

***ALLOW** sufficient time for participants to respond.*

INDICATE THAT dyeing at the top stage is the most popular mode of dyeing for worsted products.

EXPLAIN THAT dyeing at this stage allows:

- continuity of colour by blending multiple dye batches to form large lot size
- the formation of mélange, multi-colour or 'heather' yarns (yarns formed from fibres of different shade or depth of colour).

NOTE THERE are some disadvantages of dyeing worsted top:

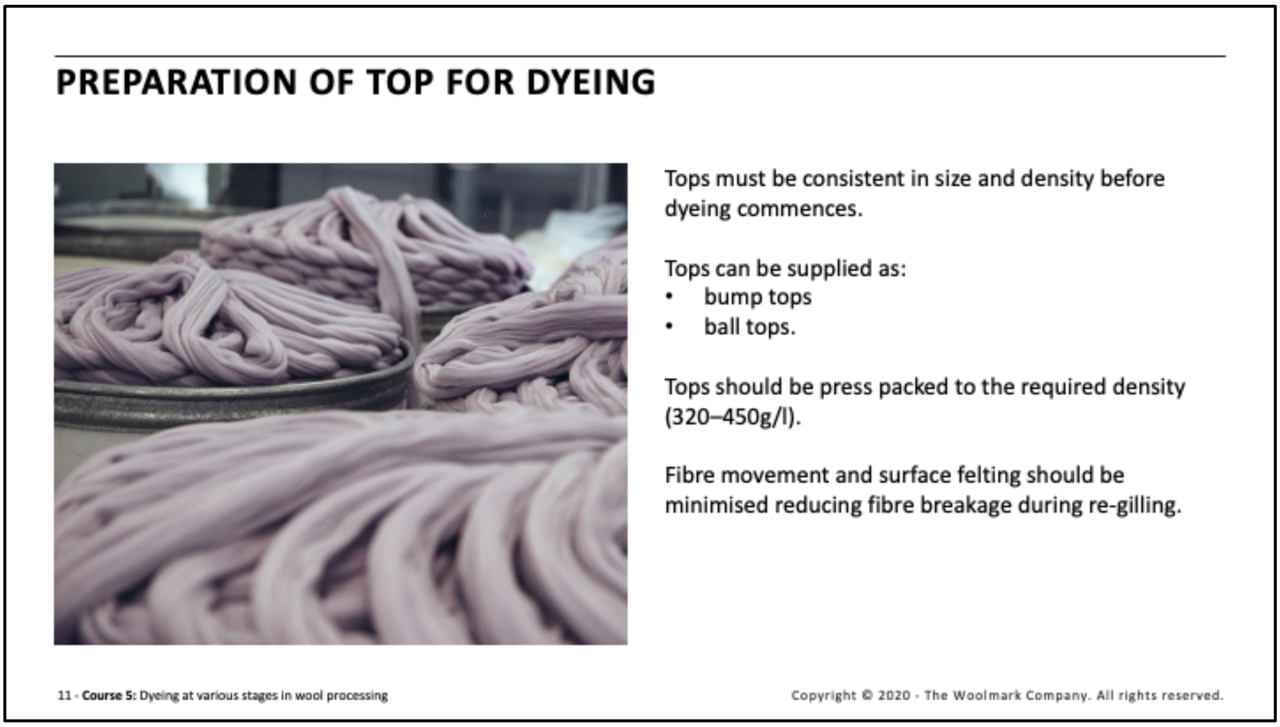
- Top must be re-combed and gilled after dyeing to restore the performance during spinning (adding to the cost of processing).
- Even following re-combing and gilling, the spinning efficiency of dyed top is lower than that of the equivalent ecru (undyed) top. This reflects the damage to the fibre caused by the dyeing conditions.

MENTION THAT worsted top can also be printed with one or more colours to create multi-colour or multi-tone effects in the spun yarns. The most common form of printing is called 'Vigoreux' printing (as shown on the slide).

A black–white mélange (or other colours) is created by printing sections of the top black, avoiding the need to blend black and white top.

The printed top is steamed to allow the dyestuff to penetrate the fibre.

EXPLAIN THAT auxiliaries that promote migration are used in the print paste in addition to those used to control paste viscosity.



NOTE THAT an important step in preparing top for dyeing is to ensure the tops are consistent in size and density. Uniformity of the tops helps minimise channelling of dye liquor and therefore unlevelness in the dyed top.

MENTION THAT top-makers can supply tops in two forms — bump tops or ball tops.

Bump tops, supplied by the top-maker normally meet these requirements. Most top-makers will wind bumps to customers' requirements to ensure they fit the dyeing machines available.

INDICATE THAT a typical bump weight is 10kg — tops heavier than this may be too difficult to handle manually, when wet. There are some worsted top dyeing systems that use one large top per carrier (up to 100kg), (e.g. the Big Form from Obem).

EXPLAIN THAT ball tops are often wound at the dyehouse and vary widely in quality. It is vital ball tops are prepared to close specifications of weight and density. Sufficient tension in winding is required to ensure the tops do not distort during handling.

NOTE THAT reducing the rates of liquor flow through the tops minimises the risk of fibre movement and surface felting, leading to less damage during the re-gilling process following dyeing.

A further step in achieving uniformity of density in the dyeing machine is to 'press pack' the tops.

POINT OUT that the required density of the top will depend on the type of machine, the pump capacity and the wool quality (i.e. typically 350g/l but can be between 320–450g/l).

MACHINERY FOR FIBRE DYEING — TOP

Water is an increasingly costly resource.

A liquor: goods ratio of 8:1 is now quite feasible for wool fibre dyeing.

Batch-wise rinsing is preferable to overflow rinsing:

- more effective than overflow rinsing
- uses less water than overflow rinsing.

12 - **Course 5:** Dyeing at various stages in wool processing

NOTE THAT water is an increasingly costly resource for wool dyers, as such it is important to minimise its use from environmental and economic standpoints.

INDICATE THAT the liquor:goods ratio of the dyeing machine is a major factor determining water consumption. Values of 8:1 are now quite feasible for wool fibre dyeing.

Full machine loads also contribute to saving water.

EXPLAIN THAT batch-wise rinsing (by re-filling the machine to operating levels with fresh water) following dyeing is preferable to overflow rinsing (adding fresh water until the machine overflows) as it:

- is more effective in removing contaminants
- uses much less water.

FIBRE DYEING — TOP

The following Woolmark Company video provides an overview of the worsted top dyeing process.

PLAY *video (1:50 minutes)*

AS THE *video plays note:*

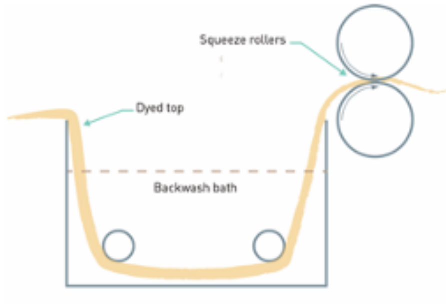
- *the even packing of the top into the dyeing cage to prevent channelling and uneven dyeing*
- *the two types of dyeing machines shown – rectangular and circular (the latter is used for pressure dyeing).*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond.*

MACHINERY FOR FIBRE DYEING — BACKWASH OF TOP

Backwash showing bowls and squeeze rollers



14 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT it is normal practice to continuously wash top after dyeing (especially black and navy) to remove:

- unfixed dye
- residual auxiliaries.

EXPLAIN THAT this process (outlined on the slide) is called backwashing and it improves the subsequent processing performance of the top.

BACKWASHING
The following Woolmark Company video provides an overview of the dyed top backwashing process.

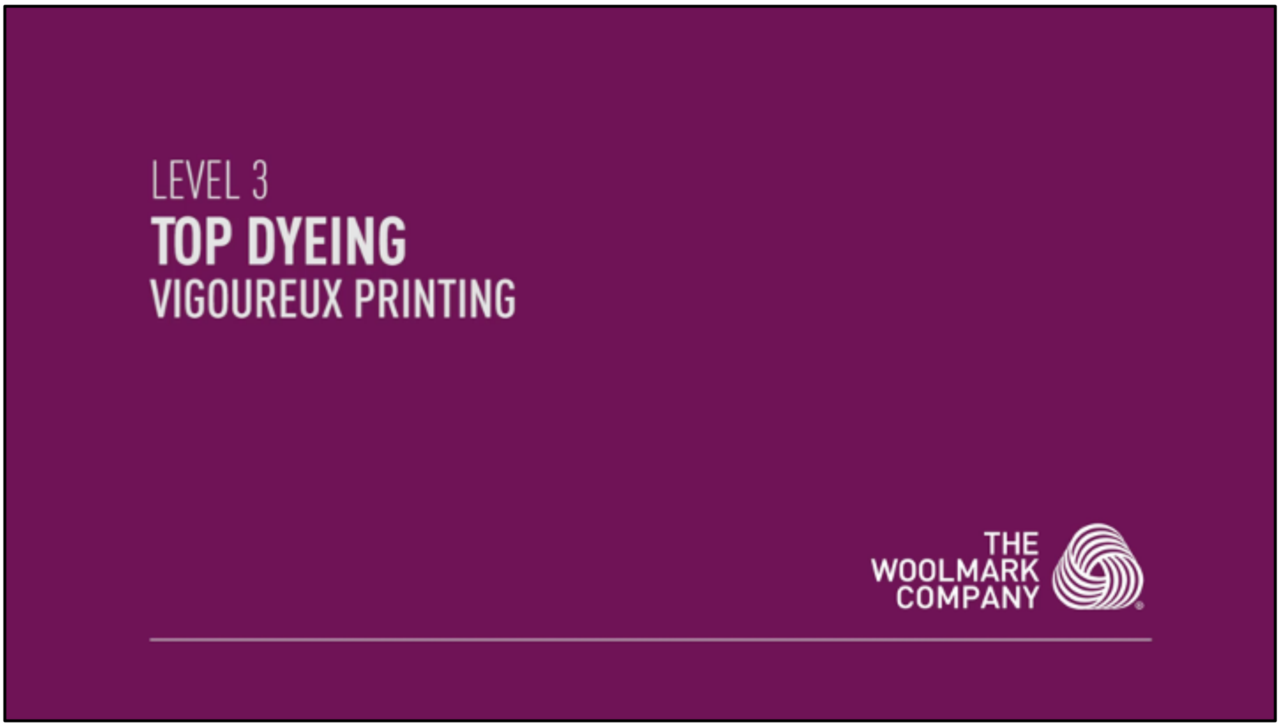
PLAY *video (53 seconds)*

NOTE THAT *tops are backwashed in a continuous washing range.*

AS THE *video plays note the state of tops after dyeing – distorted and tangled.*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond.*



EXPLAIN THAT the Vigoreux printing process is a printing technique use to produce mélange top.

EXPLAIN THAT the following Woolmark Company video provides an overview of the Vigoreux printing process.

BEFORE PLAYING the video, indicate that during the Vigoreux printing process the top is run between a pair of rollers. The bottom roller is slotted and dips into the print paste. The coloured paste, held by the slots, is transferred to the top.

NOTE THAT the amount of dye applied to the top depends on the size and pattern of the slots in the bottom roller.

EXPLAIN THAT the top is subsequently steamed to allow the dye to penetrate and migrate into the fibres.

NOTE THAT continuous steamers are also available for steaming the printed top.

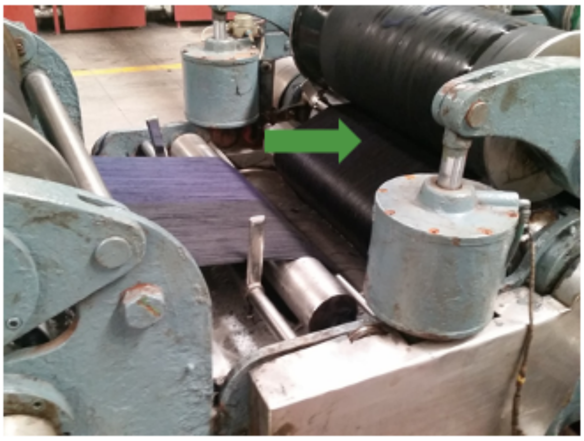
EMPHASISE THAT Vigoreux printing avoids the need to blend black and white tops to create mélange yarn.

***PLAY** video (2:29 minutes)*

***ASK** participants if they have any questions or comments regarding the video content.*

***ALLOW** sufficient time for participants to respond.*

MACHINERY FOR FIBRE DYEING — TOP DRYING



De-watering (squeeze)

Thermal drying

17 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT mechanical de-watering systems for dyed top include mechanical drying (centrifugal hydroextraction and squeezing through rollers). Squeeze rollers are normally part of the backwashing process.

NOTE THAT it is important to minimise the water content of dyed fibre to residual moisture levels of about 40–45% before the thermal drying process. This reduces the time and cost of thermal drying. The reduction in time of drying can limit any damage to the fibre.

POINT OUT that mechanical drying is followed by thermal drying (using radio frequency or hot-air dryers). The thermal dryer should be sufficiently large to dry the fibre to 17% moisture at no more than 100°C. Higher temperatures can lead to fibre damage (yellowing) and reduced processing efficiency.

Continuous hot air dryers are commonly used as the final component of the backwash machinery.

EXPLAIN THAT radio frequency (RF) drying is increasingly used for all shades of dyed top. Conveyor belt types of RF dryers are the most common for dyed top. Some RF dryers dry the balled top and can generate high temperatures in the centres of tops.

NOTE: Careful control is necessary when drying pale or bright shades, or bleached white wool, to minimise yellowing at the package centre.

FIBRE DYEING — QUALITY CONTROL

Colour-matching booth

Shade match
- To meet the customer's requirements.

Levelness
- Within the limits imposed by subsequent blending.

Fibre damage
- To prevent poor performance in processing and waste.

Fastness
- To meet processing and customer requirements.

18 - **Course 5:** Dyeing at various stages in wool processing

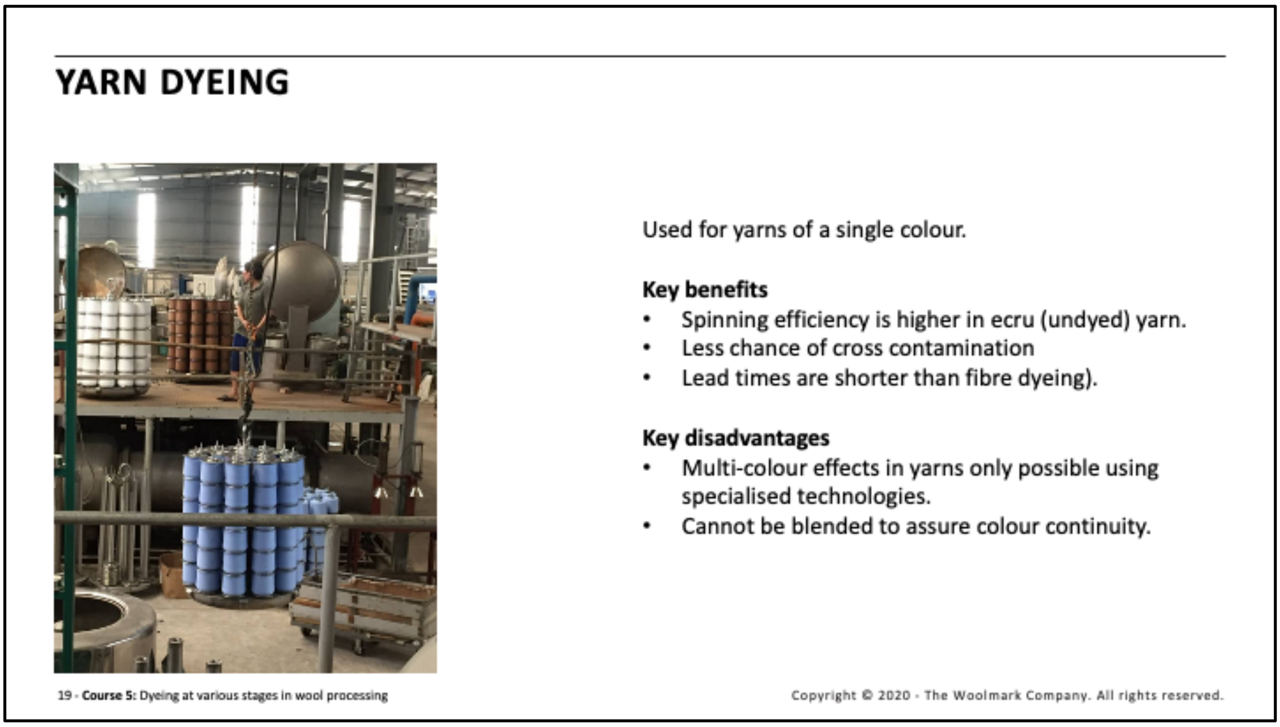
EXPLAIN THAT quality control is a key part of the fibre dyeing operation.

Shade match — The dyeing must be 'on shade' within the limits agreed with the customer.

Levelness — Every dye batch should be checked visually for shade levelness when it is unloaded from the dyeing machine. If the degree of unlevelness exceeds the acceptable level the batch must be re-loaded and levelled or, if this is not possible, overdyed to a deeper shade.

Fibre damage — Assessing fibre damage is important for spinning. It is important to measure fibre length before dyeing and after carding (woollen system) or re-combing and re-gilling (worsted system). Excessive loss of fibre length is an indicator of damage during dyeing.

Fastness — The need to check fastness properties depends on the end use of the dyed fibre. Tests should be carried out on all new shades and representative samples of established shades. For fibre that will be used in critical applications, such as machine-washable products, fastness test should be carried out on all dye lots.



EXPLAIN THAT the cost of dyeing at the yarn stage is normally higher than for loose fibre or worsted top, but there are both economic and logistical advantages of dyeing in yarn form.

- Spinning efficiency is higher for ecru (undyed) fibre. There are fewer end breaks and less chance of cross contamination between coloured fibres.
- Ecru (undyed) waste is more valuable than coloured (dyed) waste.
- Yarn dye lot sizes can be varied, minimising waste.
- Small batch sizes can be handled efficiently.
- Reduced stocks of coloured wool are needed.
- Colour decisions can be made later to meet consumer and fashion demands. Lead times can be less than one month, although more typically are about six weeks. Tolerances on shade matching and levelness are normally tighter than with fibre dyeing where there is an opportunity to blend out colour differences.

INDICATE THAT yarn dyeing imparts a single colour for the yarn — multi-colour effects in yarns only possible using specialised technologies.

MENTION THAT tone-on-tone effects can be achieved by blending (prior to dyeing) fibres that have had different pre-treatments to increase or decrease dye affinity.

YARN DYEING — PREPARATION AND DYE SELECTION

Yarn preparation
- Dry spun yarns — no scouring, rinse only at at 50-60°C.
- Woollen-spun yarn — removal of lubricant (maximum of 1.0% extractable matter recommended).

Dye selection
Worsted knitting and weaving yarns — require fastness to wet processing:
- 1:2 metal complex, acid milling, proprietary mixtures, chrome or reactive dyes
- chrome and reactive dyes for black and navy shades
- modified 1:1 metal complex for duller pale and medium shades (low pH can cause impact subsequent knitting operations).

Woollen weaving yarns — require fastness to fabric milling processes:
- acid milling, 1:2 metal complex, chrome or reactive ranges
- reactive dyes used for machine washable products, supplemented by dyes from the above ranges.

20 - **Course 5:** Dyeing at various stages in wool processing

Preparation of yarns for dyeing
EXPLAIN THAT many worsted yarns, particularly dry spun yarns, are dyed without pre-scouring or with just a rinsing process at 50–60°C.

NOTE THAT if lubricant needs to be removed, for example with woollen-spun yarns, then packages should be scoured with:
- sodium bicarbonate 1–2 g/l
- non-ionic detergent 1–2 g/l

and run for 20 minutes at 50°C, drained, rinsed with hot and cold rinsewater.

Scouring to achieve a maximum of 1.0% extractable matter is recommended.

Dye selection
EXPLAIN THAT worsted knitting yarns need to be fast to wet processing. Suitable dyes for worsted knitting yarns include:
- 1:2 metal complex
- acid milling
- chrome
- reactive dyes
- proprietary mixtures of dyes.

INDICATE THAT for black and navy shades, chrome and reactive dyes are mainly used to give the necessary wet fastness.

EXPLAIN THAT for many duller pale and medium shades, modified 1:1 metal complex dyes have sufficient wet fastness and the advantage of excellent levelness. However, the low pH used with these dyes can sufficient damage the yarn to cause concerns in subsequent knitting operations.

MENTION THAT woollen weaving yarns require fastness to fabric milling processes. Dyes from acid milling, 1:2 metal complex, chrome or reactive ranges are suitable.

For machine-washable products, reactive dyes, supplemented by dyes from the above ranges can be used.

For worsted weaving yarns the dye selection depends on the type of fabric and anticipated finishing route.

YARN DYEING MACHINERY


Hank dyeing


Package dyeing

Hank dyeing
- Enhances the bulk of the yarn.
- Used for hand knitting and some machine knitting yarns.

Package dyeing
- Can reduce the bulk of the yarn.
- Used for weaving and machine knitting yarns.
- Lower liquor:goods ratio (lower water usage).

21 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT there are two types of dyeing machine used to dye yarns — hank and package dyeing machinery.

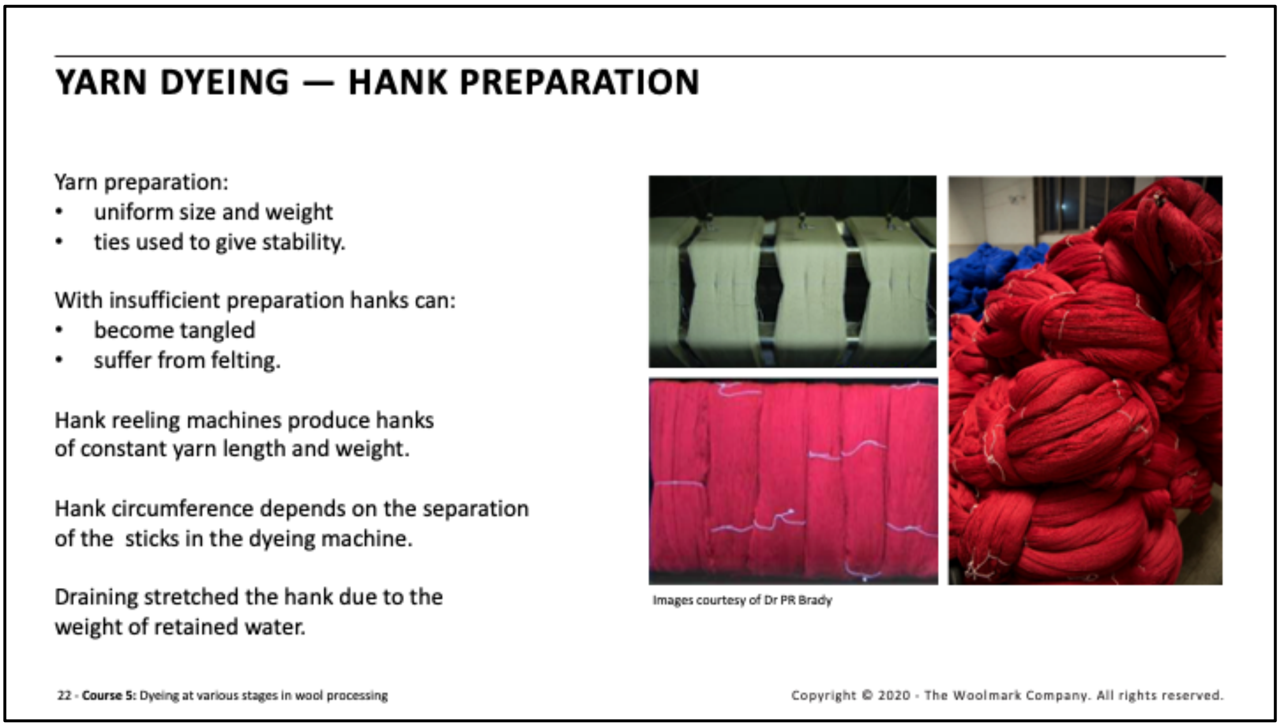
The choice between hank and package dyeing depends on the nature of the yarn.

Hank dyeing
EXPLAIN THAT hank dyeing is normally carried out for knitting yarns, where bulk and handle are critical parameters.

NOTE THAT an additional winding processes is necessary for hank dyeing so this process is slightly less efficient than package dyeing. Hank dyeing machines generally operate at a higher liquor:goods ratio than package dyeing machines, requiring greater water and energy usage.

Package dyeing
Package dyeing is normally carried out for weaving and some knitting yarns.

EXPLAIN THAT package dyeing bulky or soft twist yarns can lead to a loss of bulk and often a leaner handle in the final product. Package dyeing is more suited to weaving yarns, where bulk is not as important as in knitting. Package dyeing can sometimes be used for knitting yarns by using anti-setting technology, which is discussed in a later module.



EXPLAIN THAT substrate preparation is vitally important in hank dyeing — the aim is to wind hanks of uniform size and weight.

MENTION THAT ties are used to provide stability during handling. Hanks can become tangled with inadequate ties or by felting during dyeing. This will greatly reduce the efficiency of re-winding, and introduce knots and splices into the yarn. Ties used to control the hanks during dyeing are shown on the slide. The process of inserting these ties is sometimes called leasing.

NOTE THAT hank reeling machines produce hanks of constant yarn length and weight. The required circumference of hanks depends on the separation of sticks holding the hanks in the dyeing machine.

INDICATE THAT the necessary hank circumference must be determined for each yarn type, with an allowance for the degree of contraction during dyeing. A mismatch of hank circumference and stick separation will stretch the yarn or leave it too slack in the machine.

A circumference around 1.5m is normally used. Assessment of the suitability of hank circumference must be made when the dyeing machine is filled.

NOTE THAT draining the hanks will result in some stretch — due to the weight of retained water.

YARN DYEING — HANK DYEING MACHINES

Hank dyeing machine

Cabinet types are widely used:

- traditional, rectangular and front loading
- modular design can accommodate variations in lot sizes.

Top-loading machines:

- vertical pressure kier machine used for tops and packages
- can be used for hanks with a suitable carrier.

Sticks used at both the top and bottom of the hanks

Upper sticks used only if sticks rotate and circulate liquor:

- reduces stick marks
- minimises flattening of the yarns.

Spray dyeing machines also used.

23 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT traditional, rectangular, top-loading machines and front-loading, cabinet-types are used for hank dyeing. These machines can often accommodate variations in lot sizes and may be loaded without a crane.

EXPLAIN THAT with a suitable carrier, the vertical or horizontal pressure kier dyeing machine, used for tops and packages, also can successfully dye hanks. The liquor circulation capacity of these top and package-dyeing machines is normally more than sufficient for hank dyeing.

NOTE THAT hank dyeing machines for Merino wool yarns should have sticks at both the top and bottom of the hanks, except for specific designs in which the upper sticks rotate and have liquor circulating through the upper stick.

EXPLAIN THAT machines with a single, rotating stick, (often with liquor circulation through the stick, are ideal for:

- reducing stick marks (undyed or paler-dyed areas where the hank has been in contact with the stick)
- minimising the flattening of the yarns in areas that have been in contact with the stick.

An example of this type of machine is discussed later.

NOTE THAT the issue of yarn flattening can be overcome by using anti-setting technology (which is discussed in a later module).

HANK DYEING — CABINET DYEING MACHINES

Critical shade levelness and reproducibility achieved.

- Accurate time/temperature controllers
- Hanks loaded in a uniform manner (little flexibility in machine capacity).
- Sufficient liquor flow
  - High enough to achieve shade uniformity
  - Low enough to avoid yarn movement and/or felting.
- The optimum flow rate depends on
  - the machine type
  - loading,
  - the nature of the yarn
  - hank size

24 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT the criteria for colour matching and shade levelness is more critical in hank dyeing than in fibre dyeing. Unlike fibre dyeing colour differences cannot be eliminated by blending dye batches.

INDICATE THAT cabinet dyeing machines are fitted with accurate time and temperature controllers as a minimum level of automation.

POINT OUT that hanks are loaded on the sticks on the carrier ('dressing' the hanks) in a uniform manner. This means there is often little flexibility in the capacity of these machines, unless the machine is designed to work with a flexible number of chambers.

EXPLAIN THAT liquor flow needs to be sufficiently high to achieve shade uniformity, but low enough to prevent yarn movement and/or felting. The optimum flow rate depends on the machine type and loading, the nature of the yarn and hank size.

HANK DYEING – SPRAY DYEING MACHINES

Developed for delicate yarns:

- cashmere
- wool and wool blends
- natural silk yarns and blends with wool.

Hank rotation by rotation of arms:

- allows for easy loading and unloading
- regulation of liquor flow rate to ensure constant flow at varying loads
- even liquor distribution
- hank rotation
- variable load and liquor ratio.

Operates under pressure if required.

Source: http://www.lorisbellini.com/en/prodotti/abep-automatic-spray-hank-dyeing-machine/

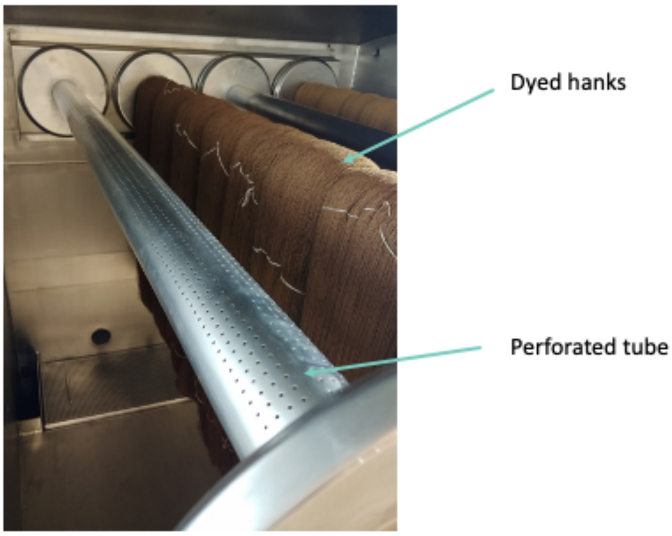
25 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT spray dyeing machines have been developed to hank dye a wide range of yarns, but are especially suited to delicate yarns, such as wool cashmere.

EXPLAIN THAT the ABEP machine from Loris Bellini is claimed to be a new technical development, which can be used to hank dye delicate yarns.
The machine features :

- extractable arms, making hank loading and unloading operations easier
- a constant pre-set liquor flow-rate for a wide range of loads
- liquor distribution to the sprayer arms, designed to ensure an even flow-rate across all arms
- a hank rotation system to prevent stick marks and unevenness.

HANK DYEING – SPRAY DYEING MACHINES



26 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT this image shows a partially unloaded spray dyeing machine used to dye yarn hanks.

NOTE THE perforated tube through which the dye flows. These machines can be used partially loaded if the tubes not carrying hanks are 'blocked off'.

POINT OUT that the strings used to hold the hanks are clearly visible.

YARN DYEING — HANK DRYING

Centrifugal hydroextraction

Radio frequency dryer

Centrifugal hydroextraction reduces the moisture content of dyed wool yarns to 35–40%.

Hot air dryers:

- Hanks are suspended on 'poles'.
- Controlled air flow and rotating yarn carriers
  - increase the rate of drying
  - reduce flattening of yarn in contact with carrier.
- Drying temperatures as low as 75°C are possible (reducing the risk of thermal damage to the fibre).

Radio frequency dryers:

- Hanks are loaded on the belt in a uniform manner.
- Air flow over the drying hanks
  - prevents the inner sections of yarn rising to temperatures above 100°C
  - reduces risk of yellowing of bleached whites or pastel shades.

Images courtesy of Stalam SpA

27 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT as with fibre dyeing, It is necessary to remove excessive water from the dyed hanks by hydroextraction before thermal or radio frequency (RF) drying.

Centrifugal hydroextraction aims to reduce the moisture content of dyed wool yarns to 35–40%,

EXPLAIN THAT after hydroextraction, hanks can be dried in hot air or RF dryers. In hot air dryers the hanks are suspended on 'poles'. In RF dryers they are placed on a conveyor belt (as shown on the slide).

NOTE THAT some hot-air hank dryers are quite sophisticated, featuring:

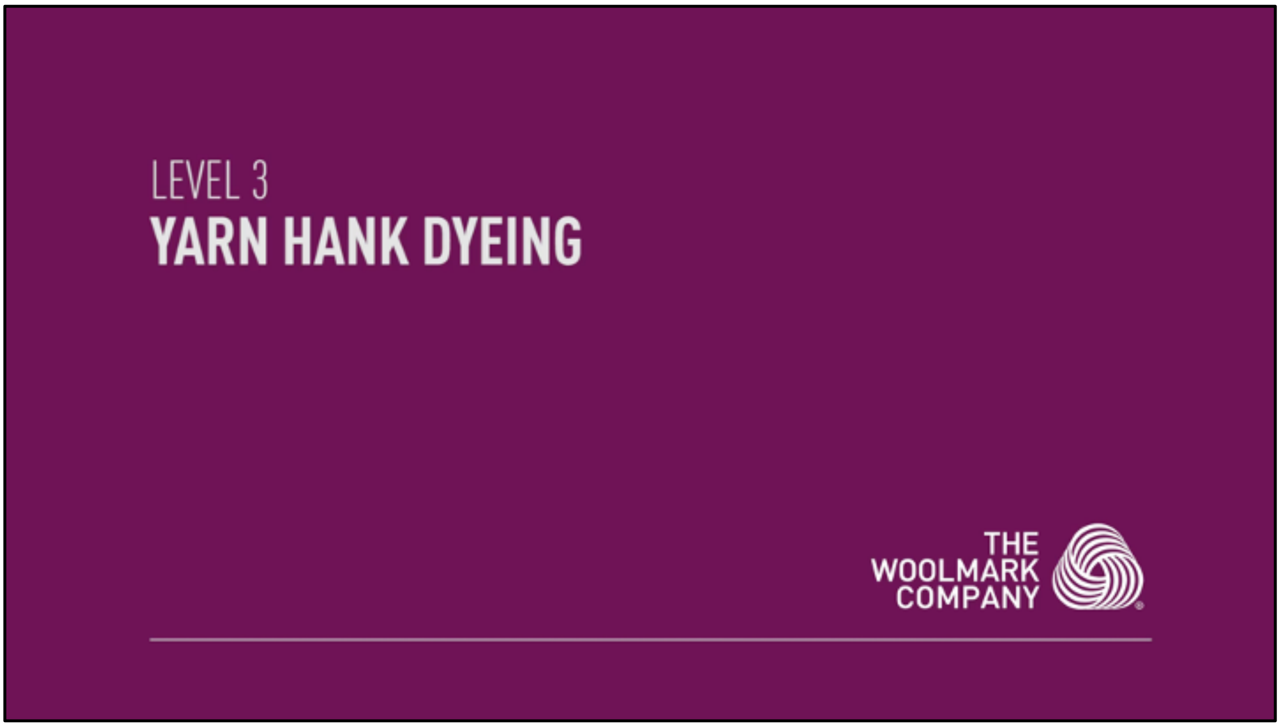
- controlled airflow and rotating yarn carriers increased rates of drying
- reduced flattening of the yarn in contact with the carrier.

Drying temperatures as low as 75°C are possible for wool, reducing the risk of thermal damage to the fibre.

POINT OUT that **radio frequency drying** also is an established process for hanks. Hanks must be loaded on the drying belt in a uniform manner if consistent residual moisture levels are to be achieved.

EXPLAIN THAT machinery provides air flow over the drying hanks to:

- prevent the inner sections of yarn rising to temperatures above 100°C
- reduce yellowing of bleached whites or pastel shades.



EXPLAIN THAT the following Woolmark Company video provides an overview of the hank dyeing and drying process.

PLAY *video (2:28 minutes)*

AS THE *video plays note:*

- *the hanks are relatively unconstrained, so too much agitation inside the machine can cause entanglement*
- *the two types of dyeing machine.*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond.*

YARN DYEING — PACKAGE DYEING

Package being loaded for dyeing

Yarn is wound onto suitable centres in preparation for dyeing.

Many types of centres are available:

- Cones
  - traditionally the most widely used package centre for wool and wool blend yarns.
- Tubular packages
  - most-widely used centres
- Stainless steel springs

Improved yarn package centres:

- Plastic cylinders, springs and non-woven centres
- Precision-wound centres, normally without or with low compression
- Random-wound centres, loaded and compressed axially.

29 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT in preparation for package dyeing, yarn must first be wound onto suitable 'centres' (described later) of which there is a great diversity.

EXPLAIN THAT cones were traditionally the most widely-used package centre for wool and wool blend yarns. Metal or plastic cones with, typically, a 4°20' taper, require spacers between each cone on the dyeing spindle, leading to the possibility of cone slippage and dye liquor leakage. Cones cannot be press packed, to give more uniform density and improved levelness of dyeing.

NOTE THAT as a result of the challenges with cone packages, tubular packages are now most widely used.

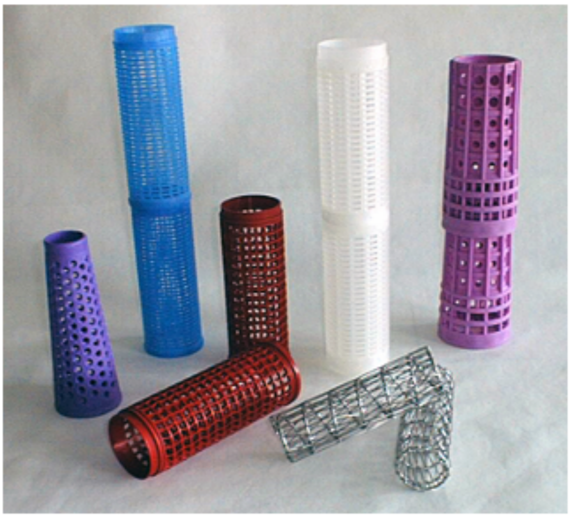
POINT OUT that stainless steel springs also have been used for many years and allow axial compression of packages.

INDICATE THAT a number of other improved yarn package centres have been developed:

- Plastic cylinders, springs and non-woven centres designed to produce a parallel or nearly parallel sided dye-pack.
- Precision-wound centres loaded on the dyeing spindles, normally without or with low compression. The non-compressible centres are designed to interlock.
- Random-wound centres, which are loaded and compressed by 15-20% axially.

NOTE THAT these new centres tend to have greater diameters than traditional cones. Larger-diameter dyepacks can be dyed with lower liquor flow rates to avoid damage to the yarns.

YARN DYEING — PACKAGE PREPARATION



Package centres

The ideal packages for dyeing have:
- a standard diameter, width and weight
- uniform density throughout each package.

Factors driving package formation:
- Precision winding (ideal winding angle 25-40degrees)
- Package compensation
- Yarn tension
- Shogging motion

30 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT the ideal packages for dyeing have
- a standard diameter, width and weight
- uniform density throughout each package.

NOTE THAT the control of each of these parameters depends on the setting of the winding heads.

Precision winding

POINT OUT that precision winding is expensive, but:
- gives higher, more uniform density (avoids patterning, ribboning and variations in density)
- can be done as step precision winding, avoiding problems in precision winding

EXPLAIN THAT the key parameters that drive ideal package formation are:
- **Winding angle** — The ideal winding angle is 25-40 degrees. In most instances 35 degrees is the preferred winding angle, for which split drums winders are used.
- **Package compensation (density and weight)** — The density of the package is affected by the pressure on the drive drum. The increasing weight of the package is offset by counterbalance.
- **Yarn tension —** Yarn tension is adjusted by altering the weight on the tension device and is affected by winding speed.
- **Shogging motion** — The 'shogging motion' (side-to-side motion) of the winder is important in package formation. It is used to generate soft edges on a wound package. The precision with which the edges are wound affects packing of the prepared packages. The split drum, or traverse mechanism, is displaced from side to side by up to about 4 mm. Consequently the yarn at each end of the traverse is displaced and does not build up in one position

NOTE: Parallel-sided packages are ideal for robotised loading, as they require no spacers. Even if manually loaded, parallel-sided packages are more efficiently handled than traditional cones.

QUALITY CONTROL OF PACKAGE PREPARATION

- All winding heads should use the same tension setting.
- Keep the tensioning device clean.
- All the spinning centres have the same length and diameter.
- Wind properly conditioned yarn.
- Replace the spinning tubes on all the winding positions at the same time.
- Precision and random winding machines have additional separate requirements.

31 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT during the winding of dye packages the following "rules" should apply:

- All winding heads should use the same tension setting.
- Keep the tensioning device clean, and operational.
- Avoid using small or odd sized centres.
- Ensure all the spinning centres have the same length and diameter.
- Only wind properly conditioned yarn.
- Replace the spinning tubes on all the winding positions at the same time.

Precision winding

- Do not use too dense a cross-over setting, this can result in too high a package density.
- Periodically check the yarn tension to ensure the end winding tension is not too high.
- Check all the packages have the same pressed density.
- Do not over compress the package columns.
- To avoid damage to the packages and carrier, make sure the press plate, spindle and packages are properly aligned, before compressing the load.

Random winding

- Use only the one type of winding drum on the machine.
- If random winding, use the same cross-over angle on all heads (33–41 degrees).
- To avoid ribboning, install and use anti-patterning attachments.
- Check for the smooth start-up of a new package — take care to see the first layers are properly wound.
- Reject any packages which show signs of 'sloughing off' (yarn falling off the end of the package).
- Ensure the wound yam covers the perforations of the dye package.
- Adjust the winding head settings so all positions produce a package of the same size and weight, within a tolerance of ± 2.5%.
- Round the edges of conical packages before dyeing.
- Use the correct patterning and traverse control when changing from conical to cylindrical packages.

YARN DYEING — PACKAGE DYEING MACHINERY

Vertical kier

Horizontal kiers

- Can be loaded and unloaded without cranes.
- Sagging of packages may be an issue.

Vertical kiers

- Cranes required

Centre	Flow rate (l/kg/min)
Cone	30
Parallel-sided	15–20

32 - **Course 5:** Dyeing at various stages in wool processing

NOTE THAT several types of package dyeing machines are available from a range of manufacturers.

The older style of rectangular, horizontal-loaded machine, has limited flow characteristics and therefore less press packing is possible.

MENTION THAT circular machines are available in both horizontal and vertical design.

Horizontal kiers
In these machines, cranes are not needed for loading and unloading. However, sagging may occur and lead to leakage of dye liquor with these machines.

Vertical kiers,
EXPLAIN THAT vertical kiers (shown on slide) need lifting equipment, and headroom for loading, but have additional flexibility and are flexible in their use, allowing dyeing of both packages or tops.

Most modern package dyeing machines are automated — both the dyeing process and the loading or unloading.

NOTE THAT it is common to have machines with a range of capacities, to handle different lot sizes.

EXPLAIN THAT liquor flow rates for wool package dyeing must be sufficiently high to ensure level dyeing, but low enough to avoid damaging the yarn and distorting the package.

The necessary flow rate to achieve levelness depends upon the package type, machine characteristics and liquor to wool (liquor:goods) ratio.

NOTE THAT recent developments in vertical kier design provide flexibility, using different numbers of carriers or different heights.

Liquor ratios are kept constant by adjusting the liquor level, which is maintained by air pad pressure.

POINT OUT that unless dyeing with very low liquor ratios, it is common with wool yarns to use liquor flow reversal throughout the dyeing process.

INDICATE THAT times for each flow direction depend on the nature of the substrate, the machine and the package type/size. The starting point is five minutes IN→OUT and four minutes OUT→IN.

MACHINERY — INDIVIDUAL TUBES

- Each spindle of dye packages has its own dyeing tube.
- The size of the machine is determined by the number of linked tubes.
- Horizontal and vertical designs,
- Machines loading is flexible — tubes can be shut off to allow for different lot sizes.

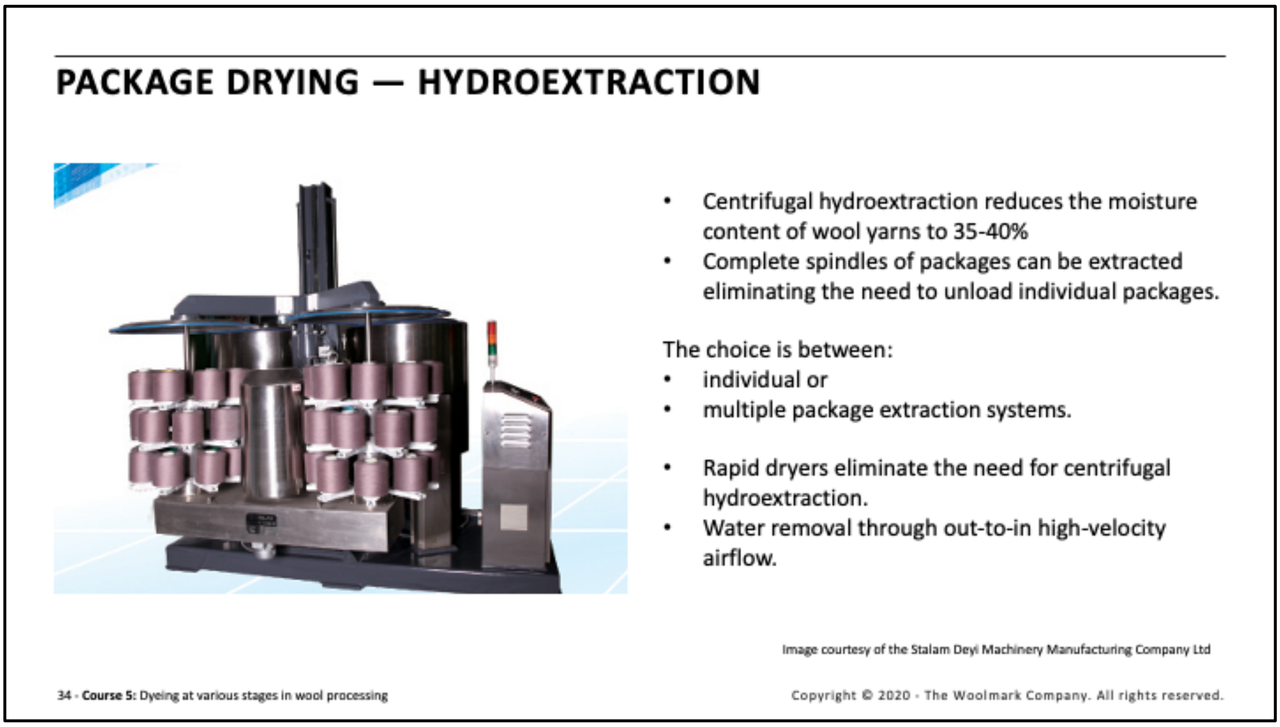
33 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT a further variation for package dyeing is the individual tube machine. Each spindle of dye packages is accommodated in its own dyeing tube (as illustrated on the slide).

NOTE THAT the size of the machine is determined by the number of linked tubes it contains. There are both horizontal and vertical versions of the individual tube dyeing machines:

- Horizontal machines (e.g. OBEM API system)
- Vertical designs (e.g. Flainox).

MENTION THAT the main advantage of these machines is that loading is flexible — individual tubes can be shut off to allow for different lot sizes without significantly impacting on liquor:goods ratios.



INDICATE THAT centrifugal hydroextraction is used to reduce the moisture content of wool yarns to 35-40%

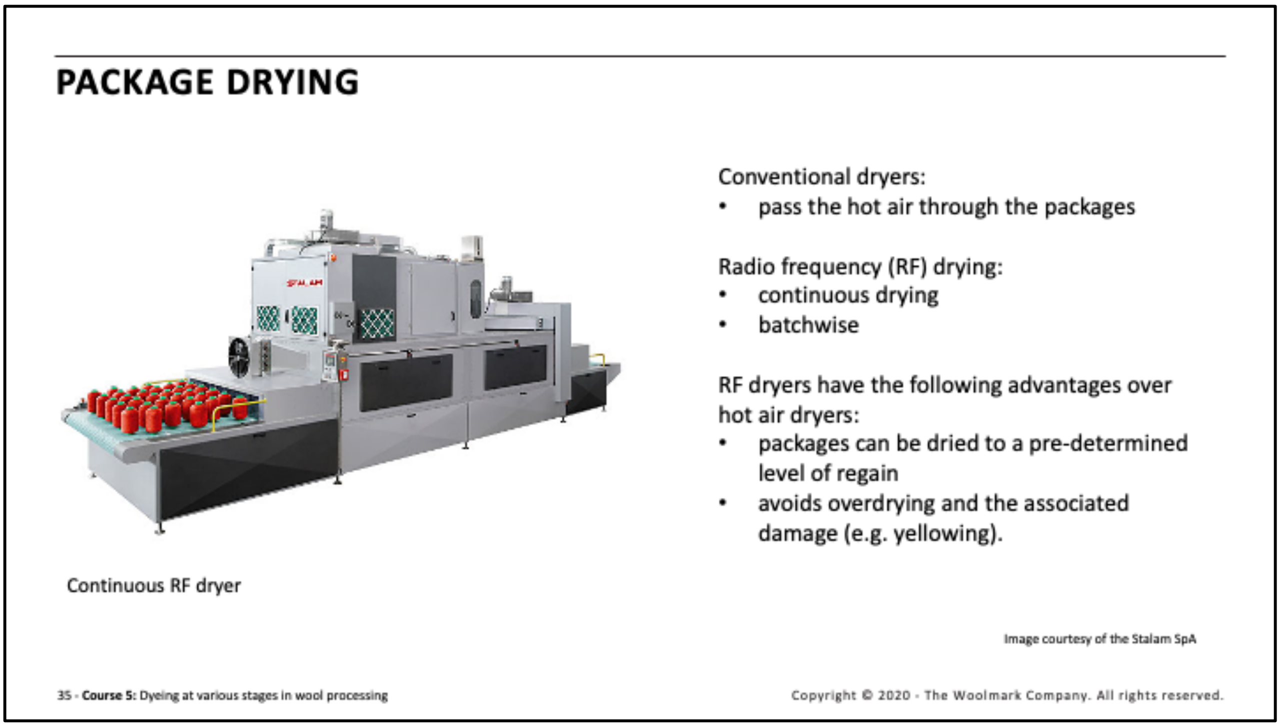
EXPLAIN THAT to avoid distortion of packages and allow higher extraction speeds to be used, some centrifuge manufacturers have introduced profiled inserts for their machines. These can allow complete spindles of packages to be extracted, thus eliminating the need to unload individual packages.

POINT OUT that the main choice is between individual or multiple package extraction systems. There are many hydroextraction systems for both individual or multiple packages.

EXPLAIN THAT rapid dryers may also be used, which eliminate the need for initial centrifugal hydroextraction by removing excess water with an out-to-in or in-to-out high velocity flow of cold air.

These systems can be incorporated into hot air dryers.

NOTE THAT rapid dryers are suitable mainly for press-packed yarns, which minimise the risk of hot air channelling and consequent uneven drying.



INDICATE THAT following the initial hydroextraction conventional dryers complete the package-drying process by passing hot air through the packages, mounted on perforated spindles.

EXPLAIN THAT radio frequency (RF) drying is an increasingly used alternative to conventional hot air systems.

There are many manufacturers of RF equipment and the machines fall broadly into two types — continuous and batchwise.

MENTION THAT with continuous drying the packages are passed on a conveyor through an RF field. With batchwise drying, the packages remain in the RF field until dry and are then removed.

Both systems have the advantage over hot air dryers that packages may be dried, with some accuracy, to a pre-determined level of regain.

This avoids overdrying and the associated damage, which can occur with hot air dryers.

NOTE THAT radio frequency drying can cause the inner sections of packages to rise to temperatures above 100°C, so machinery manufacturers have modified the operating systems, incorporating airflow over the drying packages to minimise the temperature rise.

EXPLAIN THAT batchwise systems have been developed that draw air through the packages by vacuum:

- Strayfield 'CoolDry' (UK)
- The Stalam TCRF Series.

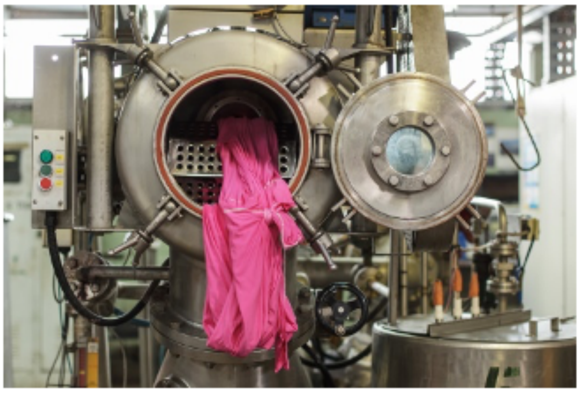
In this way the yarn is claimed never to exceed 60°C and yellowing is minimised.

NOTE TO FACILITATOR: *This is an appropriate point to break the lecture, before resuming the module at Slide 34* Fabric or 'piece' dyeing.

ASK *participants if they have any questions or comments regarding the lecture content so far.*

ALLOW *sufficient time for participants to respond.*

FABRIC OR ‘PIECE’ DYEING



Used to create fabrics of a single colour

Benefits:
- Short lead time — fast reaction to market demands.

Challenges:
- Multishade effects require specialised technologies.
- Synthetic fibre yarns of blend yarns can be used to create pin stripes.
- Tolerances on shade matching and levelness are very tight.
- Can affect the appearance of the fabric.
- Will affect fabric properties.

36 - **Course 5:** Dyeing at various stages in wool processing

INFORM participants that this slide begins the second part of Module 5 of the *Dyeing of wool — Dyeing at various stages in wool processing*.

EXPLAIN THAT fabric (or piece) dyeing can be used for both woollen and worsted woven and knitted fabrics to produce fabric of a single colour.

For most woven products dyeing at the fabric stage provides the latest possible stage of colouration and allows for quicker reaction to market demands.

NOTE THAT piece dyeing requires accurate shade matching, and excellent uniformity or levelness of shade both within and between batches.

MENTION THAT piece dyeing can affect the physical appearance of the fabric being dyed. Facing up or the development of a hairy surface can be a problem with some machines.

EXPLAIN THAT procedures are required to ensure unwanted fabric distortion and crease marks are avoided. Fabric preparation is important in controlling these parameters, but so also are machinery and process selection.

INDICATE THAT multi-colour effects in piece dyeing require specialist technologies. Inclusion, in the fabric, of synthetic fibre yarns, which do not dye or dye to different shades with wool dyes, can be used to create pin or cross stripes.

FABRIC DYEING — PREPARATION

Before dyeing the fabric should be:
- cleaned of all contaminants
- stabilised to eliminate distortions and creasing (pre-setting)

Preparation should be as consistent as possible.
Dye lots should always be assembled using fabric from the same preparation batches.

If stored after preparation and before dyeing fabrics should be:
- dried and either rolled or cuttled on a 'horse'
- stored out of direct light.

Circular knitted wool fabrics are often scoured and dyed in the dyeing machine
- May be dyed in tubular form.

37 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT fabric preparation is a critical aspect of piece dyeing.

NOTE THAT the fabric should be
- cleaned of all contaminants, such as spinning oils, dressing and waxes
- stabilised to eliminate distortions and creasing, which may otherwise occur during the dyeing process. These operations are called pre-setting.

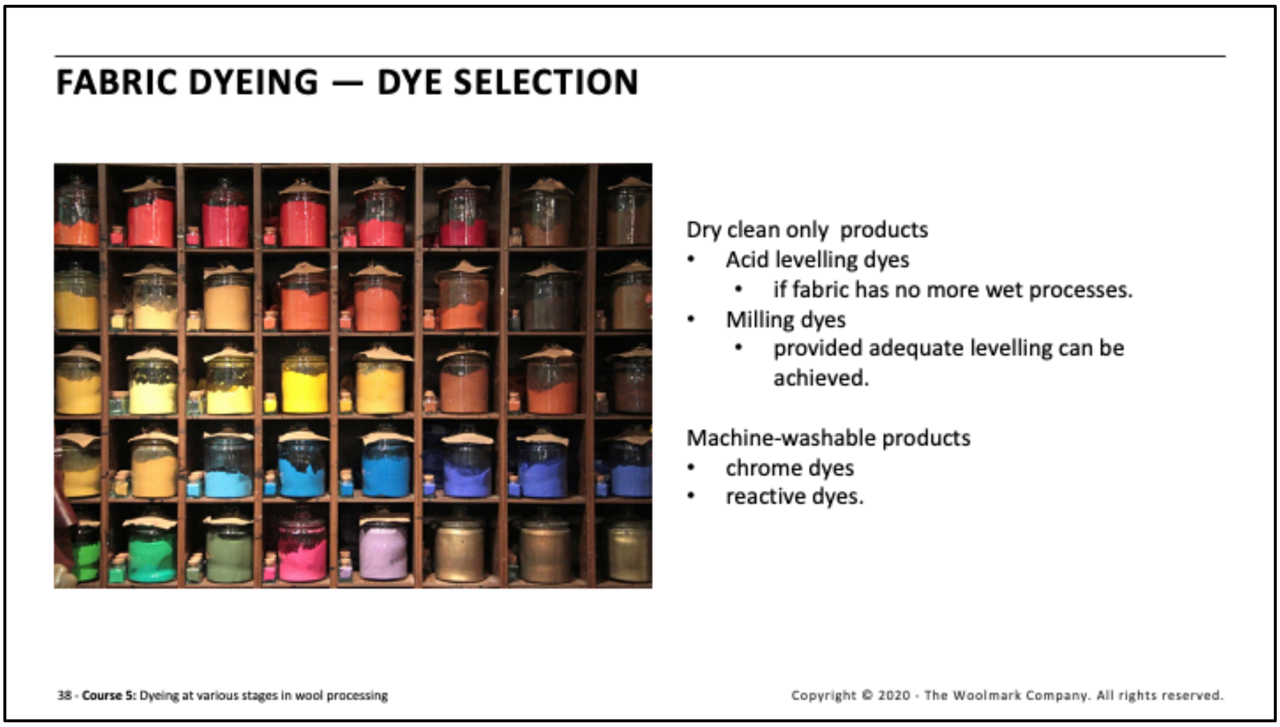
POINT OUT that preparation should be as consistent as possible. Dye lots should always be assembled using fabric from the same preparation batches to avoid differences in shade within the dye batch.

EXPLAIN THAT if fabrics are stored after preparation and before dyeing they should be:
- dried and either rolled or layered (cuttled) on a 'horse'
- stored out of direct light to prevent photo-bleaching of the outer layers of the roll, or along the folded edges of cuttled pieces.

INDICATE THAT circular knitted wool fabrics are often dyed in tubular form. Some circular knitted wool fabrics require slitting for preparatory processes, such as setting, which must be conducted open width.

EXPLAIN THAT fabrics can be re-sewn in tubular form with the face innermost for dyeing. Such a process is essential in some fabrics to prevent edge rolling, facing up and the associated running problems and crease marks.

NOTE THAT residual detergent used during previous scouring and/or milling processes can lead to foaming during dyeing, causing unlevelness. This must be removed by adequate rinsing prior to dyeing.



EXPLAIN THAT dye selection for piece dyeing depends on the requirements of the final product.

Dry clean only products — where the fabric has no more wet processes:

- acid levelling dyes
- milling dyes (provided adequate levelling can be achieved).

Machine-washable products — require dyes with good migration and wet fastness:

- chrome dyes
- reactive dyes.

Potential problems

INDICATE THAT dissolution of dyes for fabric dyeing is a critical step in the process in order to avoid fabric spots and unevenness.

NOTE THAT dye solutions must be prepared remotely from the dyeing machine to ensure powdered dye 'fly' (loose particles of dye powder) does not come into contact with the ecru (undyed) fabric.

EXPLAIN THAT even if the dyeing machine has an addition tank, it is better if dyes are dissolved in a separate area and then pumped, or otherwise transported, to the addition tank.

It is also vital the dye solution is filtered before adding to the machine to ensure no undissolved dye is added to the dyebath. This is ideally achieved by passing the dye solution through a fine stainless steel mesh.

NOTE THAT adding the dye solution to the machine needs to be controlled to ensure uniform distribution of the dye through the fabric load. An addition time of 10 minutes is ideal, particularly for dyes with lower migration properties.

FABRIC DYEING — MACHINERY

Fabric is commonly dyed in rope form.

Dyeing conditions are chosen that avoid mechanical action (development of felting).

Machinery includes:
- Overflow or soft flow jet (rope)
- winch (rope)
- jig (open width)
- beam (open width).

The most common machine used for piece dyeing is the overflow jet machine.

39 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT piece dyeing is usually carried out with the fabric in rope form. Dyeing conditions are chosen that will avoid mechanical action (and subsequent felting of the fabric during the dyeing process).

INDICATE THAT a number of machine types can be used to dye wool in fabric form including:
- overflow of soft flow jet (rope)
- winch (rope)
- jig (open width)
- beam (open width).

The most common machine used for piece dyeing is the overflow jet machine (shown on the slide).

Overflow jet dyeing machines

POINT OUT that many early jet dyeing machines were unsuitable for wool because of the severe mechanical action they impart to the fabric. Newer overflow dyeing machines have a much softer action.

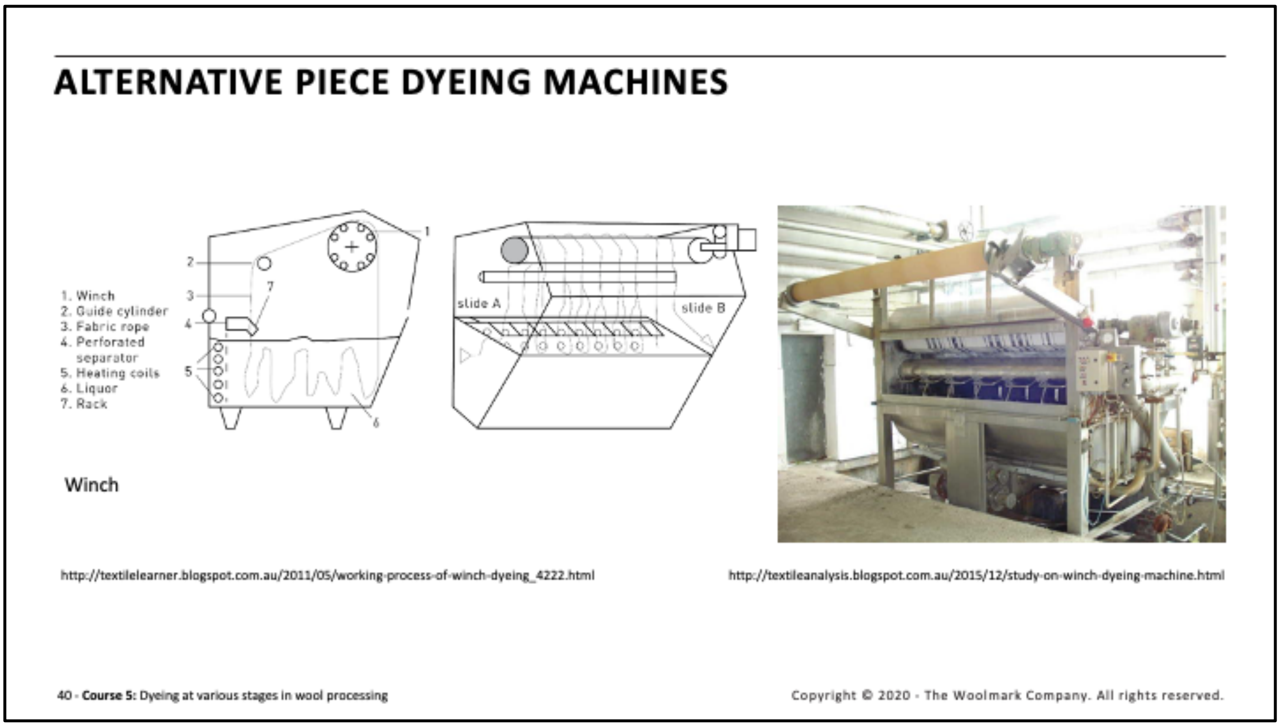
EXPLAIN THAT in this type of machine, the fabric is driven by a reel augmented by the action of jets of the circulating dye liquor. The height of the fabric drive reel, above the surface of the dye liquor, varies between machines and can affect tension in the warp direction. For knitted structures, and some loosely constructed woven fabrics, a low 'lift' machine is desirable.

NOTE THAT there are different nozzle sizes, or nozzles that can be varied in size, to ensure the appropriate balance of action and efficient circulation of the liquor.

Typical values are:

Nozzle (mm)	Fabric weight (g/running m)
60	100–200
70	150–300
85	150–500
100	400–700
120	600–900

The alternatives to overflow jet dyeing machines are covered in the following slides.

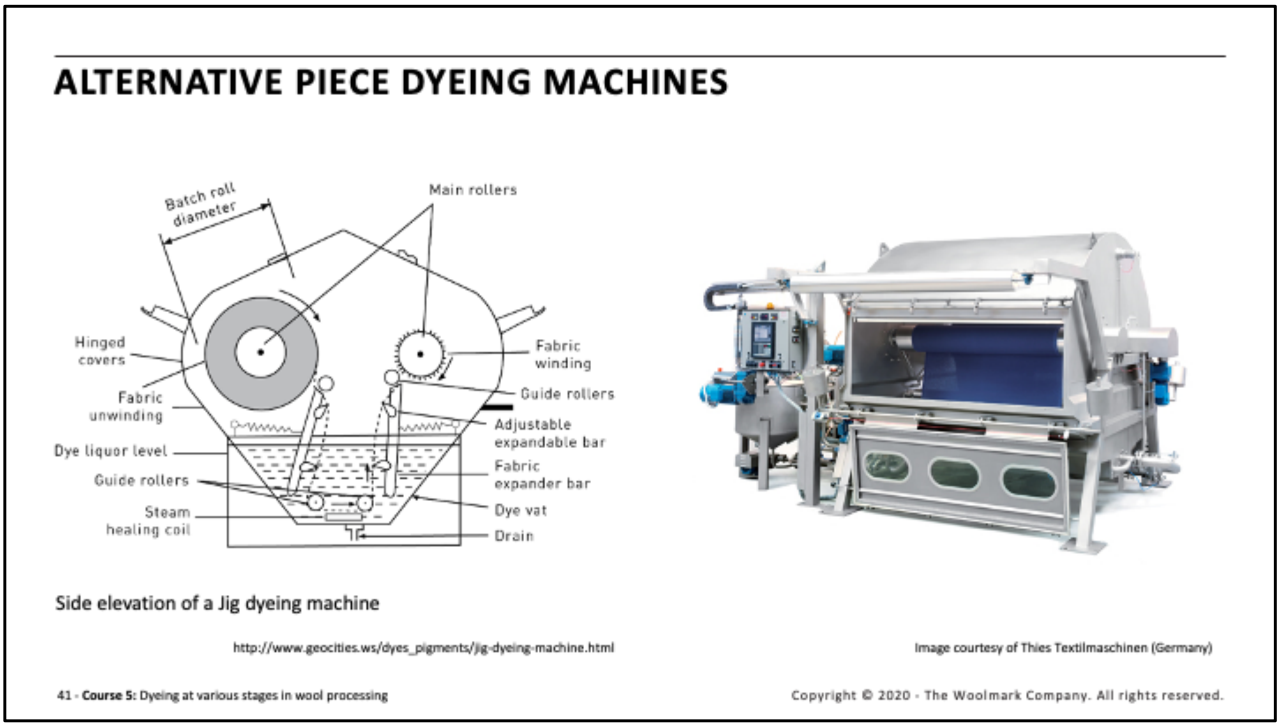


Winch dyeing machines

INDICATE THAT some traditional winch dyeing machines are still successfully used, but these have largely been replaced by overflow jet and soft flow jet machines.

EXPLAIN THAT these machines suffer two major disadvantages when compared with overflow types:

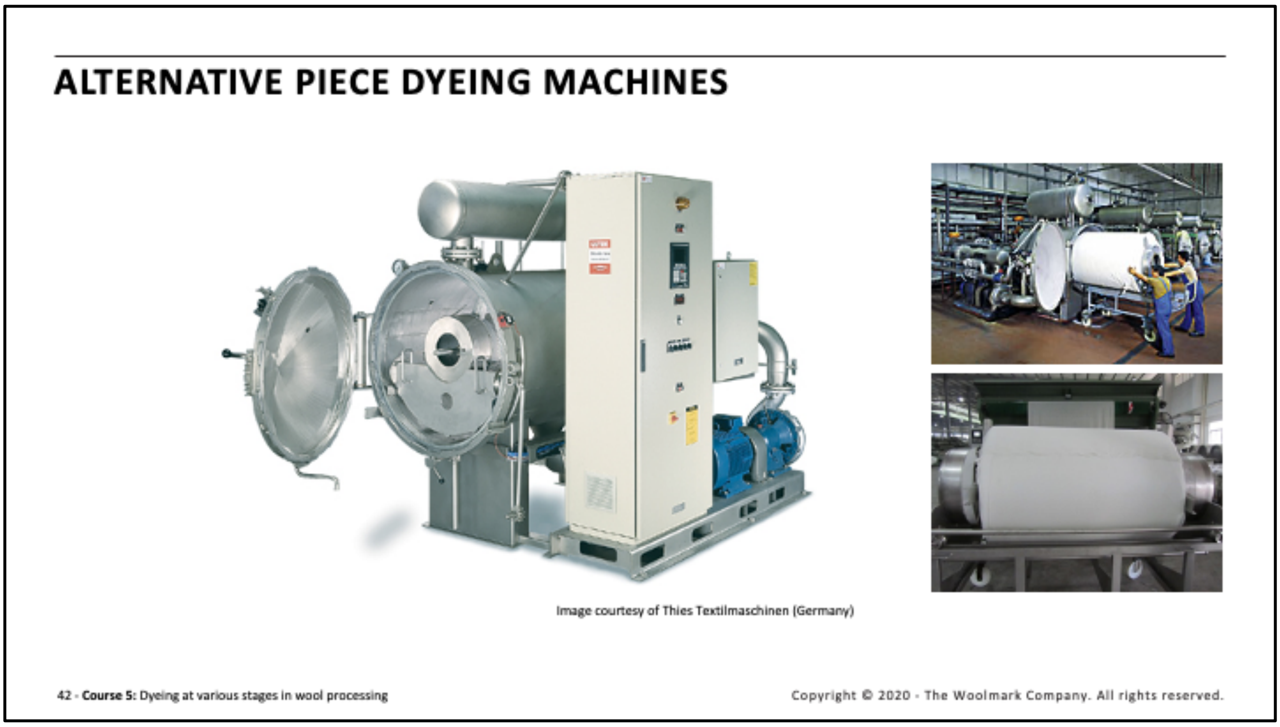
- lower rates of liquor/fabric interchange, unless there is pumped liquor circulation
- limited disturbance of the fabric rope, so that it will run in the same creases and lead to a greater incidence of running marks.



Jigger (or jig) dyeing machines

POINT OUT that these machines are widely used to dye cotton and synthetics fabrics but are rarely used for wool.

NOTE THAT it is difficult to control the tension on the fabric to avoid stretching. The stretch is permanently set and must be removed and the fabric re-set.



Beam dyeing

MENTION THAT beam dyeing of wool fabrics is also occasionally conducted.

In this method the fabric is dyed open width and the process can impart considerable flat set to the fabric.

EXPLAIN THAT beam dyeing is normally restricted to woollen-spun heavy-weight fabrics as it can result in moiré (a form of surface patterning, like watermarks caused by overlapping surface profiles) in clear-finished fabrics.

FABRIC DYEING — MACHINERY

The key components of modern piece dyeing machines are:

- the vessel
- the reel
- the overflow jet
- additions tank
- temperature and pH probes
- heat exchanger

Machinery manufacturers provide clear guidelines on all aspects of fabric dyeing particular to their machine operations.

43 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT the key components of modern piece dyeing machines, such as the overflow jet machines are:

- the vessel — normally pressure sealable, with several designs available
- the reel — for driving the fabric
- the overflow jet — for spraying the dye liquor onto the fabric
- additions tank — for adding auxiliaries and dyes
- temperature and pH probes
- heat exchanger.

NOTE THAT to achieve level piece dyeing it is necessary to achieve a minimum number of fabric passages through the overflow nozzle.

An optimum rope circulation time is 1.5–2.0 minutes. The linear speed of the fabric depends upon the fabric properties and the rope length.

MENTION THAT in most fabric dyeing machines, lubricating agents are used to facilitate the movement of the fabric through the dyebath.

INDICATE THAT wetting and de-aerating agents are helpful for all fabric dyeing and are particularly required for tightly-set fabrics on which liquor penetration can be difficult,.

NOTE THAT machinery manufacturers provide clear guidelines on all aspects of fabric dyeing particular to their machine operations.

EXPLAIN THAT the following Woolmark Company video provides an overview of the overflow jet dyeing process.

EXPLAIN THAT the overflow jet machine is one of the more popular machines for dyeing wool fabrics in piece form (hence piece dyeing).

NOTE THAT the machines come in a range of sizes to accommodate different lengths of wool fabric.

PLAY *video (1:03 minutes)*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond.*

FABRIC DYEING — AUXILIARIES

Levelling agents
- To ensure level application of the dyes.
- No opportunity for blending to ensure levelness.

Wetting agents
- For tightly-woven fabrics.

Foam suppressants
- To suppress foam generated in dyeing.
- Better to use low foam auxiliaries.

45 - **Course 5:** Dyeing at various stages in wool processing

A range of dyeing auxiliaries can be used during piece dyeing to optimise the final result.

Levelling agents and pH adjustment
INDICATE THAT levelness is of critical importance in piece dyeing. The type and quantity of levelling agent depends on the nature of dye being used and its application level.

EXPLAIN THAT the recipe must be allowed sufficient time for the levelling agent to disperse through the dyebath and reach equilibrium with the fabric. At 40°C these auxiliaries need at least 10 minutes circulation to achieve uniform distribution and equilibration with the fabric.

NOTE THAT most manufacturers now have specific products for each of their dye classes. These are designed to control exhaustion at the pH recommended for the dye types used.

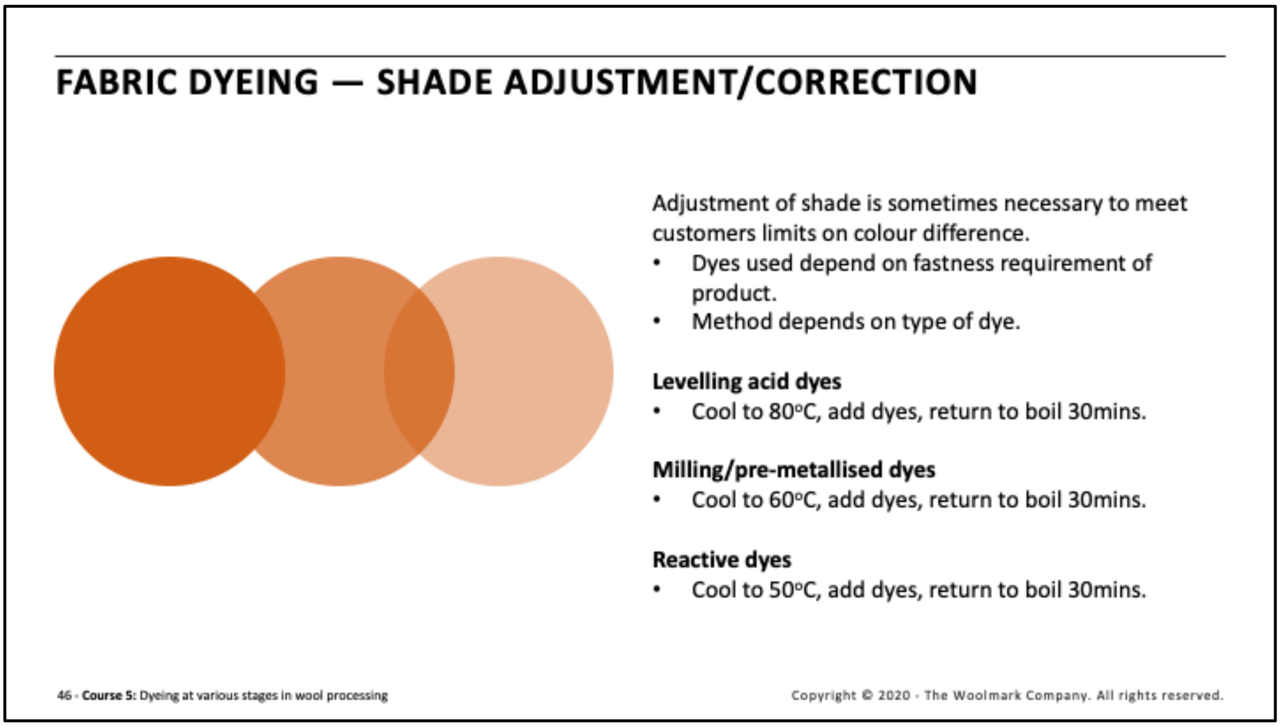
Foam formation
MENTION THAT foam formation can be an issue in overflow and soft flow jet machines. Pump cavitation can occur and floating of the fabric increases the risk of unlevel dyeing.

Auxiliaries that have low foam generation characteristics should be selected.

POINT OUT that anti-foam agents can be used but these can:
- build up on the dyeing vessel walls
- lead to spotting on the fabric.

Normally, only minimal amounts of antifoams are used to prevent foaming while avoiding the issues above.

MENTION THAT spin finishes found on synthetic-rich wool blend fabrics can interact with anti-foam agents causing difficulties during dyeing.



INDICATE THAT adjustment of shade is sometimes necessary to meet customers' limits on colour difference. The mechanism for correcting off-shade fabric dyeing depends on the mill procedures.

NOTE THAT in a right-first-time system, corrections to shades are made in a fresh dyebath in the same manner as a normal dyeing.

Alternatively, the shade can be corrected in the dyebath at the end of the dyeing process.

EXPLAIN THAT the mechanism of making shading additions to the exhausted dyebath will depend on the class of dye and the level of addition being made. For additions of 10% or less of the original recipe the following conditions are recommended:

Levelling acid dyes — reduce the temperature to around 80°C, slowly add dyes, return to dyeing temperature at 1°C per minute and run for 30 minutes.

Milling dyes — Cool to 60°C, slowly add dyes, return to dyeing temperature at 1°C per minute and run for 30 minutes.

1:2 pre-metallised — Cool to 60°C, slowly add dyes, return to dyeing temperature at 1°C per minute and run for 30 minutes.

Reactive dyes — Cool to 50°C, slowly add dyes, return to dyeing temperature at 1°C per minute and run for 30 minutes.

FABRIC DYEING — UNRECOVERABLE DYEINGS

Where a poor dyeing result is unrecoverable by adjustment or correction the dyer can:

- strip the dye and re-dye
- overdye black

https://www.researchgate.net/figure/Uneven-Dyeing-Causes-of-faults-Correct-pH-value-not-maintained-Inadequate-scouring_fig2_301699696

47 - **Course 5:** Dyeing at various stages in wool processing

NOTE THAT from time to time dyeing may be so unlevel or so far off shade it cannot be recovered by adjustment or correction. In such instances the dyer normally has two options:

- strip the dye and re-dye
- over-dye black.

Strip the dye and re-dye
Auxiliaries are available that allow the dyer to remove most of the dye from the wool fibres. This often involves the use of alkaline conditions and reductive bleaching agents (hydros etc).

EXPLAIN THAT many acid dyes can be removed in this way, however reactive dyes, which have formed a chemical bond with the protein molecule, cannot be removed.

Over-dye black
Black is a popular colour for wool products, so the dyer can re-dye the product using black dyes (chrome mordant dyed or reactive dyes) and store against future sales of products required in black.

FABRIC DRYING — DE-WATERING/HYDROEXTRACTION

Spin hydroextraction (fabric is centrifuged at high speed):

- simple
- inexpensive
- batch process in rope form
- not as even as methods below.

Suction slot:

- open width continuous process
- excess water is sucked from fabric as it passes over a narrow slot.
- forced air blast assists the suction.

Mangle:

- an open width continuous process
- fabric is squeezed between two rollers.

48 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT as with all other types of dyeing, after dyeing, the fabric must be dried. Drying using heat is expensive, so mechanical means (e.g. spin hydroextraction, suction slot or mangle) are used to remove excess water. Ideally the moisture content should be reduced to 60–70% or lower where possible before the final drying process is carried out.

Spin hydroextraction. — The fabric is centrifuged at high speed. This process is simple and inexpensive but is a batch process requiring loading and unloading.

Suction slot — An open width continuous process in which excess water is sucked from the fabric as it passes over a narrow slot. A forced air blast may assist the suction.

Mangle — In this process, the fabric is squeezed between two rollers.

FABRIC DRYING

Image courtesy of the Stalam SpA

49 - **Course 5:** Dyeing at various stages in wool processing

NOTE THAT stenter (or tenter) drying is normally used to complete the drying of the fabric following piece dyeing. This is one of the critical operations in fabric finishing. Not only is the fabric dried, but the dimensions of the fabric can be adjusted to those required. This is used to correct any stretching that may have occurred during wet processing.

Stenters may be single layered or multi-layered.

POINT OUT that normally the temperatures in each bay, or level, are independently controlled.

INDICATE THAT meters are used to monitor:

- the temperature of the air in each bay. Each bay is independently controlled
- the humidity of the air. Humidity is controlled by allowing exhaust if the humidity is too high
- the temperature of the fabric as it leaves the machine.
- the moisture content of the fabric as it leaves the stenter.

EXPLAIN THAT radio frequency (RF) fabric dryers are also available for fabric, but are not widely used (see right hand image). These machines are relatively expensive to run and do not offer adequate dimensional control to the fabric.

FABRIC DYEING — QUALITY CONTROL

Running marks

Potential Issues

- Rope or running marks
  - Permanent or semi-permanent creases in warp direction caused by set folds
- Crows feet
  - Distortions caused by uncontrolled relation of the yarns in the fabric
  - Cause by Poor setting during preparation
- Facing up
  - Fuzzy surface cause by mechanical action

50 - **Course 5:** Dyeing at various stages in wool processing

MENTION THAT there are a number of faults that can develop during piece dyeing, for which the fabric must be inspected.

Rope or running marks

These are length-wise creases, which form in the fabric and are difficult to remove. Running marks usually arise from inadequate pre-setting of the fabric before dyeing (i.e. poor fabric preparation).

Rope or running marks occur in conditions that inhibit opening of the rope during dyeing.

EXPLAIN THAT preventive measures can be taken to minimise these marks, including:

- adequate pre-setting of the fabric prior to dyeing
- increasing the fabric running speed
- reducing the rate of cooling
- reducing the machine loading
- slightly increasing the nozzle pressure or using the next largest nozzle
- ensuring the dyebath is not drained at too high a temperature.

'Crow's feet'

INDICATE THAT crow's feet are local distortions in the fabric and are also usually caused by inadequate pre-setting of the fabric.

This distortion is more prevalent in some fabric structures (e.g. plain weave woven fabric).

Preventive measures include:

- adequate pre-setting.
- higher rope speeds
- increased liquor:goods ratio.

Facing up

EXPLAIN THAT facing up is excessive hairiness on the surface of the fabric, which can occur if the mechanical interaction on the fabric during dyeing is too high.

Preventive measures include:

- reduced mechanical action using the minimum winch speed and nozzle pressure that will give an acceptable fabric cycle time
- bagging the fabric (sewing the selvedges together to form a tube) with the fabric face inside.

NOTE: Tubular knitted fabrics should always be dyed face side innermost to minimise facing up.

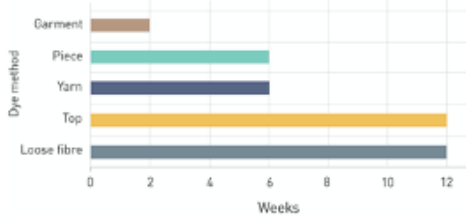
GARMENT DYEING

Most commonly used on knitted products
- Woollen-spun knitwear
- socks etc.

Rarely used for woven products.

Can be combined with scouring and milling processes in a single machine.

Short lead times — timely response to fashion cycles.



51 - **Course 5:** Dyeing at various stages in wool processing

EXPLAIN THAT garment dyeing is an important and critical colouration route for knitwear and provides a quick response route for solid-shade garments.

Some tone-on tone colour effects can be produced, but are based on fibre or yarn pre-treatments.

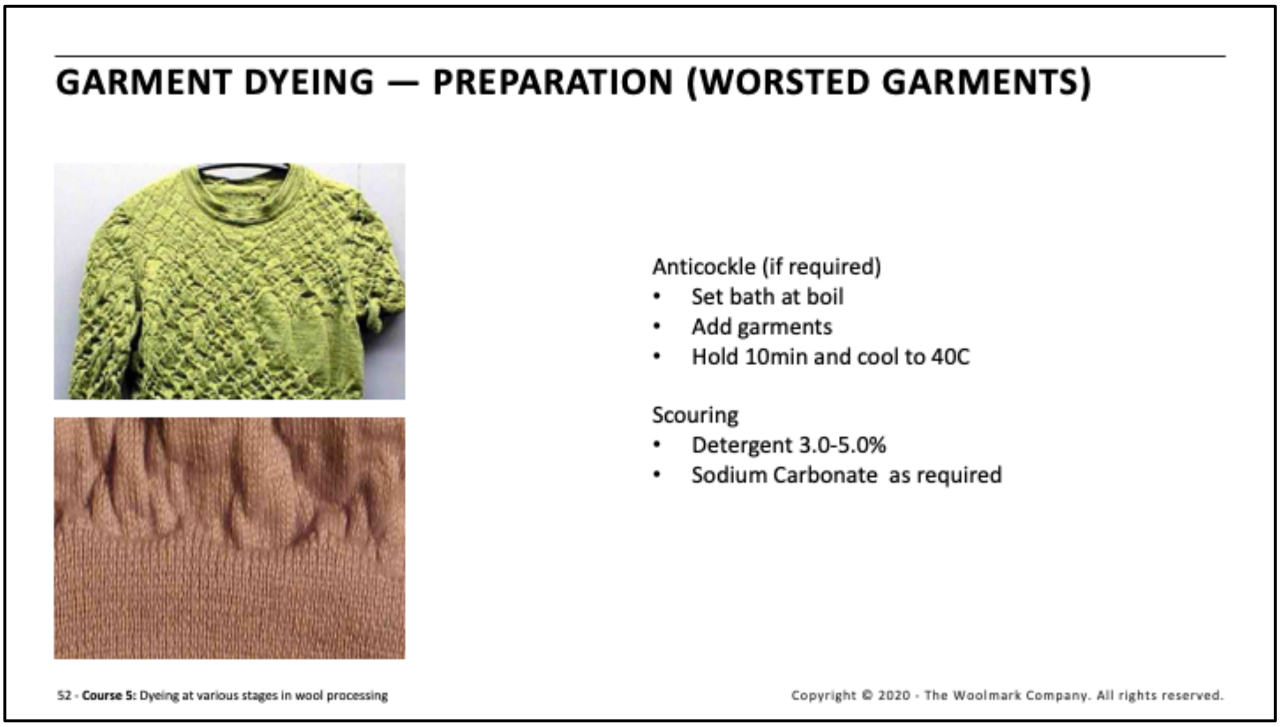
MENTION THAT the dyeing methods use to dye garments are also used for garment panels of fully-fashioned items.

INDICATE THAT dyeing of woven garments is a viable route for cotton and some synthetic fibre products, but it is not widely practised commercially on wool apparel.

It must be noted that knitwear to be dyed in garment panel or full garment form may need to be constructed differently to fibre or yarn-dyed garments if similar appearance and aesthetics are to be achieved.

NOTE THAT knitting cover factors (the tightness of knitting) may need to be changed and, in extreme circumstances, also yarn twist levels.

POINT OUT that the usual processing sequence for dyeing woollen-spun knitted garments is:
- scour
- mill
- (optional) felt-resist treatment
- dye
- apply polymer or softener (if required).



Anti-cockle treatments

EXPLAIN THAT some garments, particularly fully-fashioned worsted-spun garments, require an anti-cockle treatment before scouring and garment or garment panel dyeing to stabilise the strains in the knit structure.

INDICATE THAT this prevents unwanted distortion of the loops in the structure, which can lead to surface distortion known as 'crow's feet'.

Anti-cockle methods

Anti-cockle processes may be carried out in a side or overhead paddle dyeing machine or in a rotary dyeing machine. These methods are outlined below.

Side/overhead paddle

- Set the bath at the boil with the paddle set to minimum speed and add the garments individually.

Rotary machine

- Load the garments in the machine and introduce boiling water from the side tank as rapidly as possible.
- Stop the paddle or rotation, but maintain the temperature at the boil.
- Hold for 10 minutes, but run the paddle (or rotate) twice, for 10–20 seconds, during this time.
- Cool gently to 40°C by slowly adding cold water, with the paddle or rotation at minimum speed.

NOTE: Dropping the bath or cooling it too rapidly will lead to permanent creases and must be avoided.

POINT OUT that unlike woollen-spun knitwear, worsted-spun knitted garments, particularly in fine gauges, require a 'clean' surface, so are not milled prior to dyeing.

GARMENT DYEING — PREPARATION (WOOLLEN GARMENTS)

Scouring
- Detergent 3–5%.
- Sodium carbonate .
- 1–2% (for saponifiable oils).
- 0.5–1.0% (if needed for other oils).
- Run time 3–15 minutes.
- Rinse hot and then cold.

Milling
- Detergent 1–3%.
- Run time up to 40 minutes (depends on level of milling required).
- Rinse hot and cold.

53 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT the preparation of woollen-spun garments for dyeing involves scouring, milling and optionally felt-resist treatment.

NOTE THAT all garments must be scoured before dyeing to remove processing oils, dirt and stains. The process for scouring is outlined on the slide.

MENTION THAT woollen-spun knitwear normally requires a milling process to achieve the desired fullness of hand and traditional surface appearance. The process for milling is outlined on the slide.

EXPLAIN THAT there are a number of factors to be considered during woollen-spun garment construction, including:
- The same yarn as that in the body of the garment is used for any linking and sewing, otherwise it will dye to a different shade.
- Tight, thick seams, such as at the point of a 'V' collar, or where arm and body seams join, can reduce the penetration of felt-resist chemicals and dyes, leading to undyed or much paler areas.
- Collars can be dyed separately (in polyester mesh bags) from the garments or the points of collars left open during the preparation and dyeing processes.

NOTE THAT woollen-spun knitted garments should always be processed inside-out to minimise surface fuzzing and 'facing up'.

GARMENT PREPARATION — FELT-RESIST TREATMENT

Loosely knitted garments may require felt-resist treatment before dyeing.

Several processes can provide different degrees of garment stability (e.g. machine washing performance.)

Processes used include:

- chlorination with dichloroisocyanuric acid (DCCA)
- oxidation with peroxymonosulphate salts (Caroat acid)

54 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT the mechanical action imparted during garment dyeing of knitwear is sufficient to cause unwanted felting or 'facing up' of loosely-knitted fine-wool products.

Undyed garments, except those knitted with yarns spun from felt-resist treated fibre, are often treated to reduce their felting propensity.

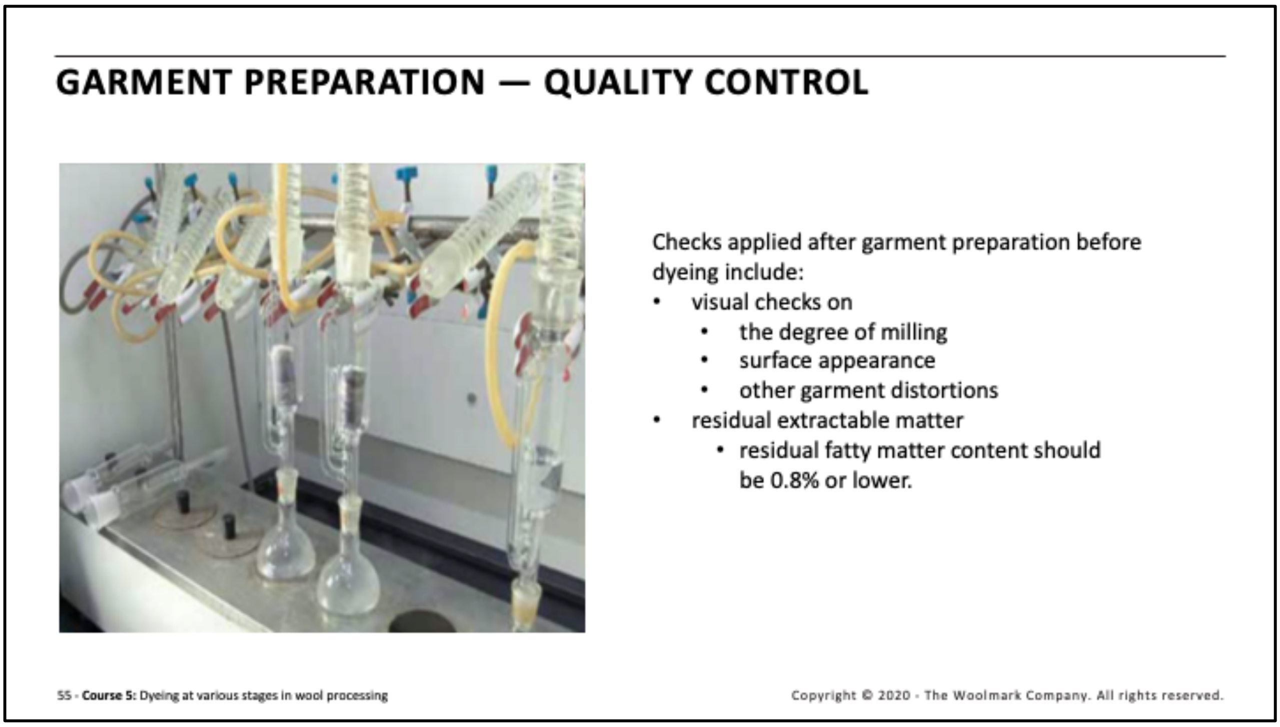
EXPLAIN THAT several processes are available to provide different degrees of garment stability. Some confer machine washing and tumble drying performance.

Processes used include :

- chlorination with dichloro-isocyanuric acid (DCCA)
- oxidation with peroxymonosulphate salts (Caroat acid).

POINT OUT that garments knitted from worsted yarns spun from felt-resist treated fibre require only scouring before dyeing.

NOTE THAT woollen-spun garments made from felt-resist wool may require additional milling to achieve the same effect.



NOTE THAT some checks must be applied after garments are prepared and before the garment is dyed.

INDICATE THAT visual checks on the degree of milling and surface appearance of scoured and scoured/milled garments is necessary to ensure the right level of milling has been achieved and it is even.

POINT OUT that residual extractable matter should be measured on a routine basis. If residual oil levels are too high the efficiency of subsequent felt-resist and dyeing processes will be adversely affected.

EXPLAIN THAT in a production situation Soxhlet extraction is normally impractical, because of the time necessary. A rapid test, such as the WIRA Rapid method is used. The results are correlated with a standard reference test procedure based on Soxhlet extraction.

A typical conversion equation is:

Soxhlet = 1.2 x WIRA Rapid value + 0.35

The residual fatty matter content (based on Soxhlet extraction) should be 0.8% or lower.

GARMENT DYEING — DYE SELECTION

Acid levelling, and 1:1 pre-metallised dyes

- used for garments that will not be subjected to washing in consumer use.

Milling acid and 1:1 pre-metallised dyes

- specific after treatments can be applied for machine washable garments.

1:2 pre-metallised and milling dyes

- limited migration properties

Reactive dyes

- exhibit good migration and wet fastness.

http://www.icssydney.com.au/index.php?id=315

56 - **Course 5:** Dyeing at various stages in wool processing

Dye selection for garment dyeing
INDICATE THAT dye selection for piece dyeing depends on the fastness requirements of the final product.

Acid levelling and 1:1 pre-metallised dyes
EXPLAIN THAT acid levelling and 1:1 pre-metallised dyes are used for garments that will not be subjected to machine washing during consumer use.
The advantage of these dyes is their ability to migrate and provide level dyeing with good seam penetration, which can be improved by extending the dyeing time at the boil.

When applied to non-felt-resist garments, dyeing times must not be extended too much, otherwise excessive felting shrinkage may occur.

Milling acid dyes
NOTE THAT some milling acid dyes may be applied in pale to medium/heavy shades on hand-wash garments.
Specific after-treatments or lighter shades may allow use on machine washable garments.

1:2 pre-metallised and milling dyes
POINT OUT that 1:2 pre-metallised and milling dyes have limited migration properties at the boil and levelness must be ensured before the dyebath reaches the temperature at which they ‘fix’ in the fibre.

Reactive dyes
EXPLAIN THAT reactive dyes exhibit good migration properties below the temperature at which they react with wool. It is important to ensure they are applied uniformly and with adequate seam penetration before the temperature of fixation is reached.
Dyeing is started at 30°C to reduce the initial rate of dye strike.

GARMENT DYEING MACHINES

Rotary machine

Side paddle

Three machines are commonly use to dye wool garments:

- rotary
- side paddle
- overhead paddle.

57 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT three machines are commonly used for garment dyeing:

- rotary
- side paddle
- overhead paddle.

Rotary machines

POINT OUT that rotary machines are generally more sophisticated than paddle machines and incorporate a range of process controls. They are considered to:

- have a more severe action allowing milling
- be more amenable to automation
- operate at a lower liquor ratios (less water).

Paddle machines

EXPLAIN THAT paddle machines have a relatively gentle action and are used where development or milling of the garment is not required. Under some conditions a side paddle machine can mill knitwear.

These machines also can be used for chemical treatments (anti-cockle or softening) where required.

GARMENT DYEING MACHINES

Rotary machines are available in several configurations
- simple types: designed for garment preparation
- side-loading types: designed for garment preparation
- front-loading types: for both preparation and dyeing.

Scouring, milling and dyeing processes can be carried out in the same machine.

For dyeing rotary machines are fitted with:
- speed and automatic time and temperature controllers
- additional electronic sophistication

For anti-cockle treatment a rapid hot-fill system is required.

Image courtesy of Brongo Srl (Italy)

58 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT rotary machines are available in two forms:
- side-loading machines are normally designed for garment preparation
- front-loading types are used for both preparation and dyeing.

Simple rotary types can be used for scouring, milling and dyeing.

EXPLAIN THAT for dyeing it is important these machines are fitted with speed and automatic time and temperature controllers. Additional sophistication, such as reversing rotation, rotation interrupt, high-speed liquor extraction, liquor level sensors, hot-fill facility, heat exchanger, auxiliary and dye mixing and addition system, etc, are also available.

For anti-cockle treatments, it is necessary to have a rapid hot-fill system.

NOTE THAT rotary machines generally operate at shorter liquor:goods ratios than paddle machines, which ensures:
- reduced water and energy consumption
- more rapid filling and draining.

GARMENT DYEING — MACHINES

Overhead paddle

Side paddle

Side and overhead paddle machines:

- for garment preparation and dyeing
- have a mild mechanical action
- are suitable for worsted garments that require a clean surface
- take longer than rotary machines to achieve the same degree of milling on woollen products.

Overhead paddle types are

- more widely used for hosiery
- have reduced liquor movement.

Side paddle types are:

- used for felt-resist and dyeing operations.

Image courtesy of Fabcare Garment & Textile Machinery PVT.LTD (India)

59 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT both side and overhead paddle machines are used for garment preparation and dyeing.

Overhead paddle types are more widely used for hosiery.

EXPLAIN THAT the mechanical action of these machines is generally lower than rotary types, which makes them suitable for worsted garments that require a clean surface, although they can also be used for woollen-spun products.

These machines take longer than rotary machines to achieve the same degree of milling on woollen products.

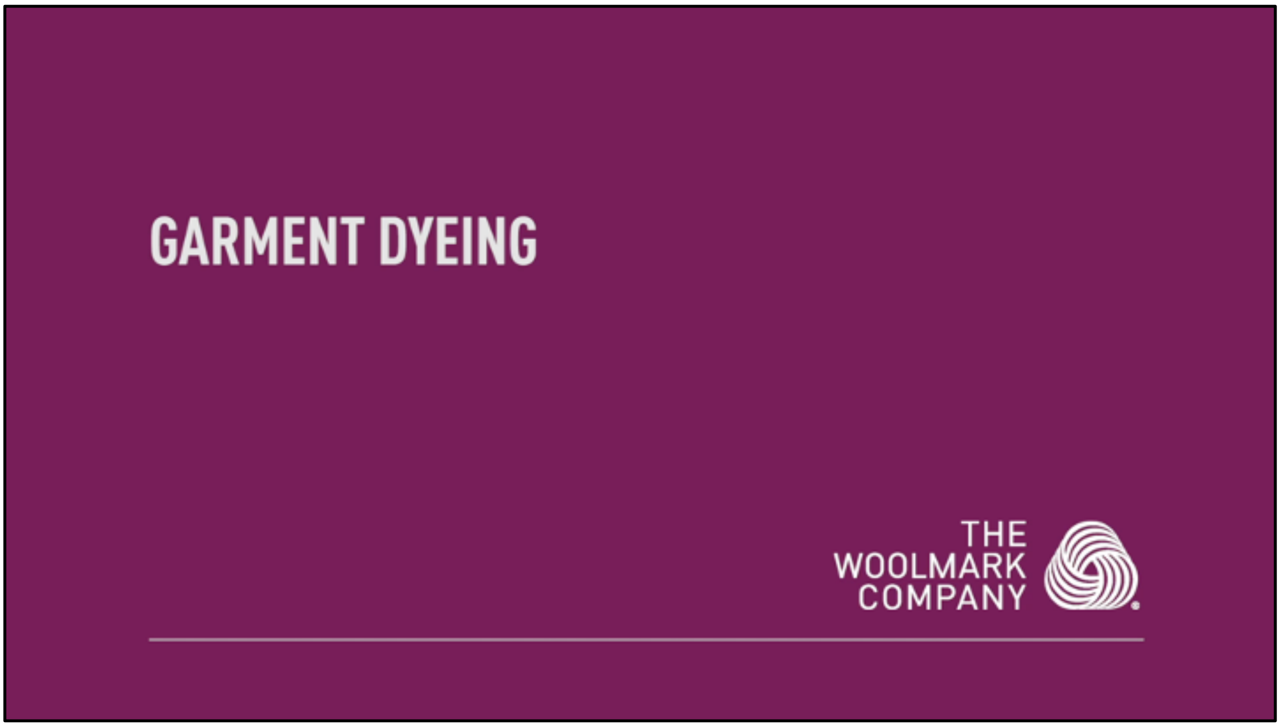
INDICATE THAT overhead paddle machines have reduced liquor movement, particularly across the width of the machine, so the uniformity of felt-resist and dyeing processes can be lower than in side paddle types.

MENTION THAT for dyes with poor migration it is essential to have a pause in the rate of temperature rise and it can be helpful to use an acid donor or acid dosing system.

POINT OUT that it is also necessary to ensure an adequate machine speed is used to achieve good garment/liquor interchange and therefore level dyeing.

Rotation speeds of 15–20 rpm should be used for paddle machines. Excessive speeds must be avoided to prevent felting

NOTE THAT overhead paddles can be used for felt-resist and dyeing operations if fitted with speed and automatic time and temperature control.



GARMENT DYEING
EXPLAIN THAT the following Woolmark Company video provides an overview of garment dyeing.

PLAY *video (3:21 minutes)*

ASK *participants if they have any questions or comments regarding the video content.*

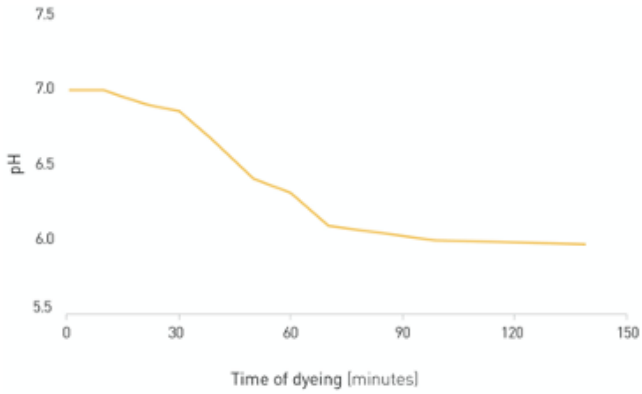
ALLOW *sufficient time for participants to respond.*

GARMENT DYEING AUXILIARIES

Wetting agents:
- ensure good penetration of seams.

Acid donors
- control pH — reducing slowly
- promote a low initial strike rate
- ensure good exhaustion at lower ph.

Levelling agents:
- ensure levelness
- ensure good seam penetration.



pH profile of acid donor product

61 - **Course 5:** Dyeing at various stages in wool processing

INDICATE THAT a range of auxiliaries is used to facilitate dyeing of garments.

Wetting/penetrating agents

NOTE THAT garment dyeing requires good liquor penetration into seams and other tightly constructed areas. Wetting or penetrating agents can be used to facilitate this penetration.

Acid donors

EXPLAIN THAT for milling and other dyes with poor migration, auxiliaries can be used to produce a more uniform rate of dye uptake and reduce the risk of unlevel dyeing. These products slowly degrade in the dyebath to release acid and gradually reduce the pH of the dye liquor (as illustrated on the slide). This allows the dyes to migrate well during the early stages of dyeing, but also gives high levels of final dyebath exhaustion.

This results in:
- increased migration and shade levelness, including seam penetration
- high and reproducible levels of dyebath exhaustion
- increased batch-to-batch shade reproducibility.

Acid donors are added at the start of dyeing. Examples include:
- Eulysin WP (BASF) 1.0–2.0g/l
- Optacid VS and VAN (Clariant) 0.5–2.0g/l

MENTION THAT a similar effect can be achieved by programmed dosing of pre-diluted acid to the dyebath. The final dyebath pH is determined by the initial pH, water hardness and quantity of acid donor used.

Levelling agents

Levelling agents can be used to:
- ensure levelness
- ensure effective seam penetration.

GARMENT DYEING — INHIBITING FELTING

Special auxiliaries are used to allow some garments to be dyed without prior felt-resist treatment.

Water soluble polymers:
- coat the wool fibre surface
- reduce fibre-to-fibre interactions, which cause felting.

These polymers are:
- added to the dyebath at the start of dyeing
- removed by normal rinsing processes.
- unsuitable for machines with high levels of mechanical action
- most applicable in paddle machines that are operated at a slow speed.

62 - **Course 5:** Dyeing at various stages in wool processing

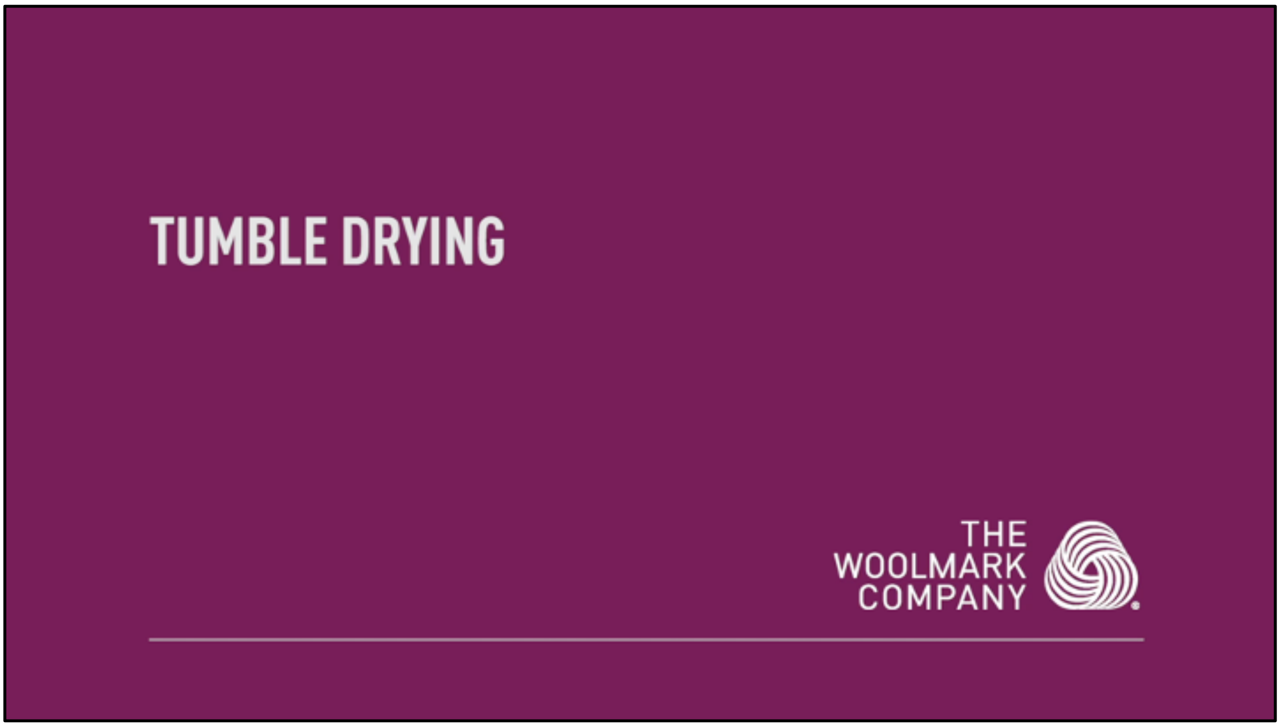
INDICATE THAT products are available that allow many types of scoured garments to be dyed without prior felt-resist treatment.

NOTE THAT water-soluble polymers are used, which
- coat the wool fibre surface and
- reduce fibre-to-fibre interactions, which cause felting.

The product is added to the dyebath at the start of dyeing and is removed during the normal rinsing processes.

EXPLAIN THAT such products are unsuitable for machines with high levels of mechanical action and are most applicable in paddle machines that are operated at a slow speed.

Examples of products are:
- Croscolor WSDS (Eurodye-CTC) 1.0–2.0%
- Meropan NF (CHT) 0.5–2.0g/l
- Nofelt WA (Tanatex Chemicals) 0.5–1.0g/l



DRYING DYED GARMENTS
EXPLAIN THAT the following Woolmark Company video provides an overview of garment drying.

INDICATE THAT there are two stages in the drying of wool dyed as garments (mechanical spin) and thermal (tumble). Both are illustrated in this video. Often they are conducted in the same machine. In this case 'the tumble dryer' has a spin cycle before the tumble drying action starts.

PLAY *video (27 seconds)*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond.*

GARMENT DYEING — QUALITY CONTROL

Pill formed on a garment

After dyeing monitor:

- shade matching
- dimensional stability testing
- levelness of shade
- general appearance
- facing up
- evidence of felting shrinkage
- handle
- contamination
- holes, cuts and tears
- size and weight

On representative batches, monitor:

- pilling
- burst strength.

64 - **Course 5:** Dyeing at various stages in wool processing

NOTE THAT quality control of dyed garments includes inspections before and after the dyeing process.

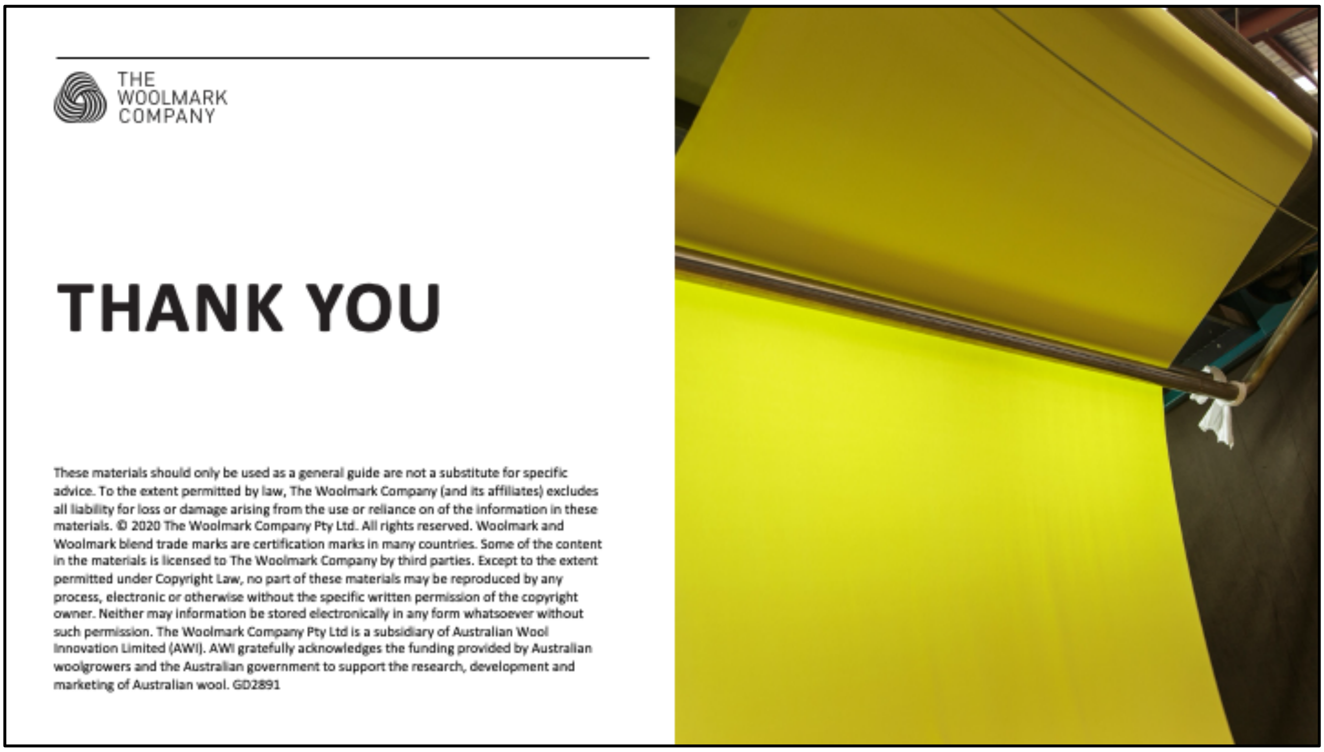
EXPLAIN THAT ecru (undyed) knitwear garments are normally checked after linking and the following list of parameters covered:

- missed stitches
- stains
- loose linking
- puckered seams
- inaccurate seaming
- thick seams
- correct linking/sewing yarn
- contamination
- holes, cuts, tears and yarn breaks
- knots (maximum four per garment)

INDICATE THAT final inspection includes:

- normal shade matching within the customer's tolerance
- dimensional stability (relaxation and felting shrinkage, according to the care label)
- levelness of shade overall and between body and seams
- general appearance – surface, creasing, etc.
- evidence of felting shrinkage
- handle
- contamination, particularly non-wool fibres
- holes, cuts and tears
- size and weight.

MENTION THAT in addition, it is normal to monitor pilling and burst strength on representative batches.



INFORM participants of the time and location for the next lecture — *Module 6 The side effects of dyeing* — and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here:
www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

MODULE 6

SIDE EFFECTS OF DYEING

RESOURCES — MODULE 6: SIDE EFFECTS OF DYEING

No additional resources are required to deliver **Module 8: Side effects of dyeing**.

WELCOME participants to Module 6 of the Woolmark Wool Science, Technology and Design Education Program — *The dyeing of wool — Side effects of dyeing.*

INDICATE THAT there are many other changes in the fibre or fabric as a result of the dyeing operation in addition to imparting colour to the substrate. Some of these changes are acceptable, or even desirable (e.g. softer handle in fabrics and some yarns). Some changes are less acceptable and require modifications to dyeing procedures or compromises in dyeing to manage any side effects.

EXPLAIN THAT this module will cover :

- damage to the fibre
- tippiness and skittery effects
- bulk in yarn
- excessive hygral expansion in fabrics
- running marks in piece dyeing
- inadequate dye fastness
- the methods of avoiding undesirable side effects
- the compromises required between damage, levelness and fastness.

INFORM participants that by the end of this module they will be able to:

- describe the types of damage that occur during wool dyeing
- describe the impact of this damage on wool processing
- describe the methods used to inhibit damage to wool during dyeing.

NO RESOURCES REQUIRED FOR THIS MODULE

DAMAGE DURING DYEING

DYES	STRENGTH (cN)		EXTENSION (%)	
Yarn type	2/48	2/56	2/48	2/56
Undyed	290	306	14.8	26.4
Acid levelling	266	263	15.1	22.4
Milling acid	250	242	12.5	16.9
1.2 pre-metallised	248	323	11.3	12.9
Chrome	260	261	12.4	19.3

2 - **Module 6:** Side effects of dyeing

EXPLAIN THAT damage to the fibre is one of the major side effects of the dyeing process. It caused by:

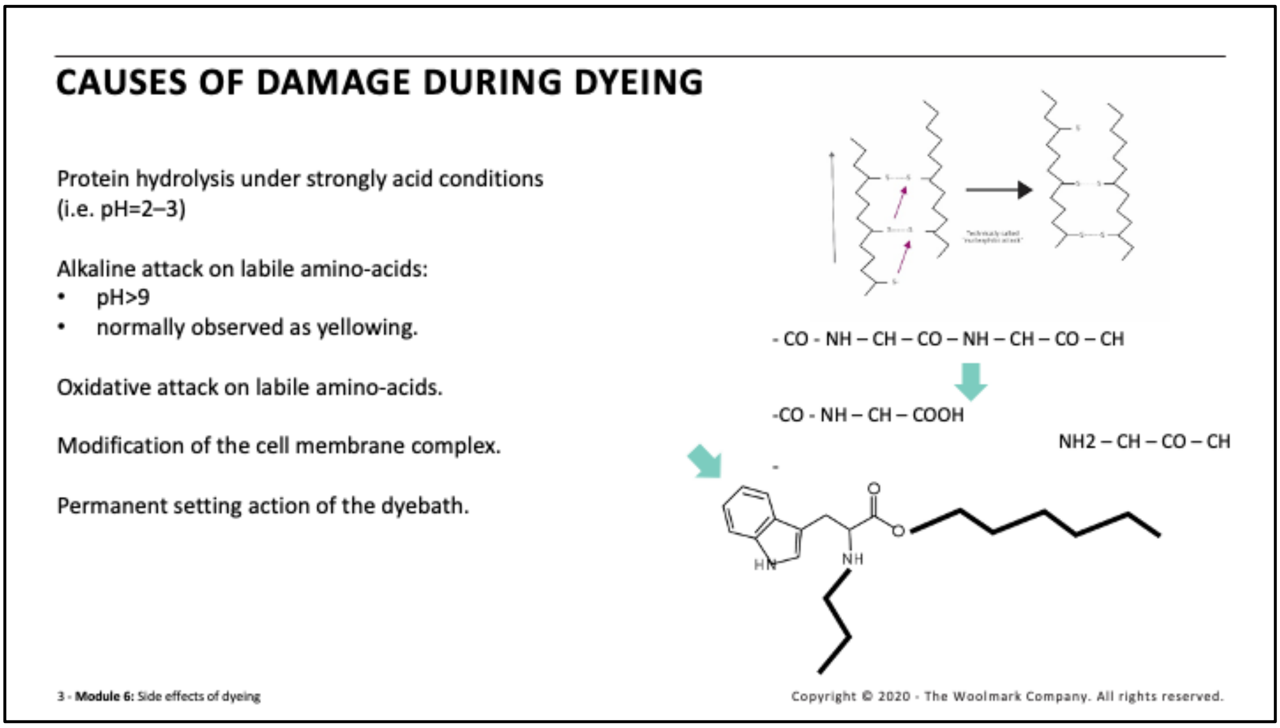
- prolonged periods at the boil when dye additions are made
- high dyeing temperatures (particularly above 100°C)
- dyeing in strong acid solutions with acid levelling or 1:1 pre-metallised dyes
- dyeing at higher pH levels with some milling dyes.

INDICATE THAT existing damage in the fibre can be exacerbated by the dyeing process. Such damage includes:

- weathering of the fibre during the growing season (e.g. tippiness — leading to skittery dyeing)
- processes before dyeing (e.g. scouring, carbonising, felt-resist treatment).

POINT OUT that the table on the slide shows the typical values for the loss of strength and extensibility of yarns after dyeing with different dye types in a CSIRO trial.

NOTE: All dyeings reduced the strength of the yarn, it was the degree of loss that changed with dye type.



EXPLAIN THAT a number of mechanisms have been proposed for the loss of fibre, yarn and fabric performance associated with damage during processing.

Hydrolysis of the peptide bonds occurs when wool is boiled in a strongly acid or alkaline dye liquor. Some protein material dissolves, causing weight loss and loss of fibre strength.

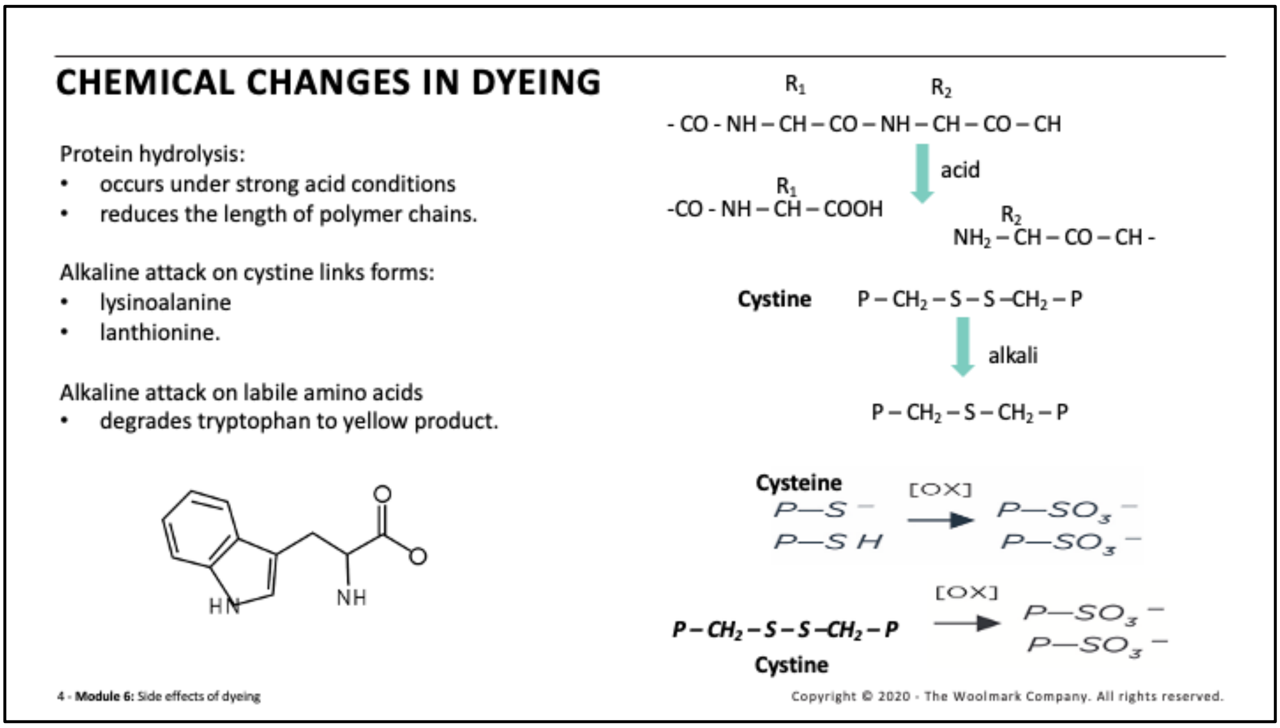
INDICATE THAT modification of the labile peptide side groups is normally associated with alkaline damage but is also caused by oxidative attack. The presence of oxygen in alkaline conditions exacerbates the damage. This damage is often seen as yellowing of the fibre.

NOTE THAT modification of the cell membrane complex can also reduce the strength of the fibre.

POINT OUT that permanent setting of fibres into new configurations contributes to a reduction in fibre strength. This damage can be reduced by inhibiting permanent setting in the dyebath, which will be discussed in this module.

MENTION THAT in conventional dyeing cycles, the level of fibre damage can be minimised to some extent by:

- limiting the period at the boil
- avoiding high temperatures, particularly above 100°C
- maintaining the dyebath pH at a value around the iso-electric point of wool (is around pH 4.5–5). Under these conditions the concentration of links between charged amino and carboxyl groups is at a maximum and, hence, their stabilising effect on the wool proteins is greatest.



INDICATE THAT the chemistry of the changes that occur during dyeing operations is shown on the slide:

- The amide groups of the protein chain are hydrolysed under strong acid conditions reducing the length of the polymer chains.
- Cystine can degrade to lanthionine and lysinoalanine under alkaline conditions.

EXPLAIN THAT cystine bonds and cysteine side groups can also be oxidised during dyeing to several forms, including cysteic acid, which:

- no longer stabilise the fibre
- makes the protein more water soluble, adding to weight losses.

NOTE THAT sensitive amino-acids, such as tryptophan, can degrade to form coloured products.

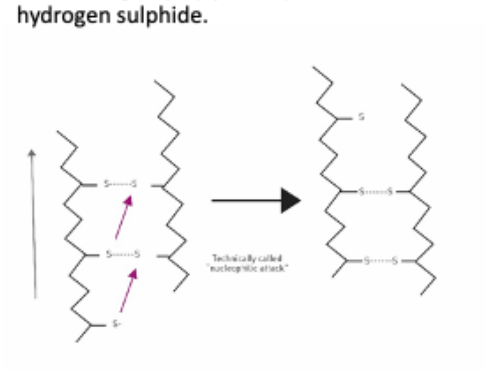
MENTION THAT non-keratinous proteins are less stable than keratin and can be attacked during dyeing leading to:

- an increase in the amount of soluble protein material removed from the wool
- a resultant weight loss in the fibre.

PERMANENT SETTING ACTION

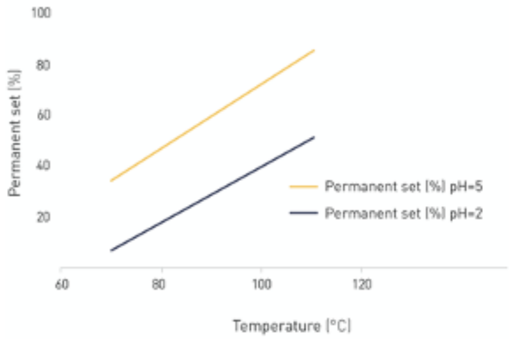
Permanent setting action of the dyebath is associated with thiol disulphide interchange and is catalysed by:

- free thiol groups (cysteine)
- hydrogen sulphide.



Permanent set is increased by:

- higher temperature
- increase in pH
- increased time (not shown below).



5 - **Module 6:** Side effects of dyeing

INDICATE THAT permanent setting is associated with thiol-disulphide interchange within the strained wool fibre.

EXPLAIN THAT this interchange is catalysed by:

- free ionised thiol groups (cysteine) in the fibre
- hydrogen sulphide that is released by chemical processes within the fibre.

NOTE THAT the effect of dyeing conditions on the amount of permanent set imparted during dyeing is shown on the slide. Permanent set is enhanced by:

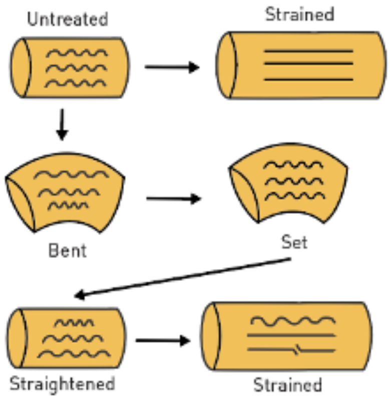
- an increase in the temperature of dyeing
- an increase in the pH of dyeing
- an increase in the time of dyeing (not shown).

PERMANENT SETTING AND DAMAGE

- The fibre is deformed (e.g. bent) during dyeing.
- Setting moves the macromolecules to a new position within the fibre.
- After dyeing the macromolecules are no longer strain free.
- Further strain causes early failure.

			TENACITY (N/ktex)		
		Set (%)	Yarn	Warp	Weft
Untreated			81	76	74
Dyed	Control	68	63	63	64
Dyed	Anti-setting	32	69	12.5	72

Proposed mechanism



Courtesy of CSIRO

6 - **Module 6:** Side effects of dyeing

EXPLAIN THAT the mostly recently proposed mechanism for damage caused by permanent setting is as follows:

- The fibre is deformed during the dyeing operation.
- The permanent setting action allows protein macromolecules to move to a new position within the fibre.
- When deformation is removed after dyeing, the macromolecules are no-longer strain free.
- Further strain causes failure before that which would occur if the macromolecules were in their original strain-free position.

This is shown diagrammatically on the slide.

INDICATE THAT the table illustrates that if permanent setting can be reduced, using anti-setting agents, the damage to the fibre can be reduced (i.e. less strength is lost).

OPTIONS FOR REDUCING DAMAGE

To reduce fibre damage during dyeing requires:
- inhibiting chemical modification
- limiting peptide chain hydrolysis
- limiting attack on labile amino acids
- inhibiting permanent setting.

Options:
- pH control
- lower temperature in dyeing
- shorter time of dyeing
- agent to inhibit permanent setting
- agents to crosslink the fibre.

7 - **Module 6:** Side effects of dyeing

EXPLAIN THAT to reduce the damage to wool during dyeing it is necessary to inhibit several processes occurring:
- chemical modification to the fibre
- peptide chain hydrolysis
- degradation of labile amino acids
- permanent setting.

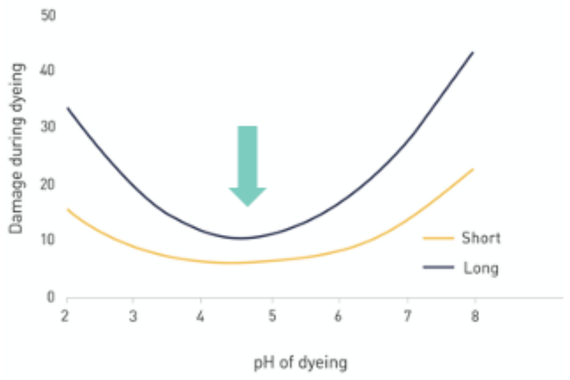
INDICATE THAT options to manage these factors include:
- pH control to stay in near the iso-electric point of the fibre
- lower temperature during dyeing
- shorter time of dyeing
- agent to inhibit permanent setting (anti-setting agent)
- agents to crosslink the fibre, which offsets the hydrolysis of the protein chains and prevent formation of soluble protein.

EFFECT OF DYEBATH PH ON FIBRE DAMAGE

Damage is minimised by dyeing near the iso-electric point of the fibre.

The region of minimum damage is:
- pH ~ 3–8 without electrolytes
- pH ~ 3.5–5 in the presence of electrolytes.

Damage due to pH is measured as:
- fibre weight loss
- fibre strength loss.



8 - **Module 6:** Side effects of dyeing

POINT OUT that the effect of pH on fibre damage to wool in dyeing has been known for many years.

NOTE THAT damage is minimised when the dye is applied at a pH near the iso-electric point of the fibre (i.e. pH 4.5–5). In the iso-electric region the salt links are maximised (as is the stability of the fibre). This is shown in the diagram for short and longer dyeing times.

EXPLAIN THAT research done many years ago showed that the amount of extracted protein (wool gelatins) is minimised if pH is in the range of pH 3-8. Below 3 and above 9 the amount of protein extracted (weight loss, damage) increases. In the presence of neutral salts, the amount of soluble protein is minimised in range pH=3.5-5.

INDICATE THAT neutral salts promote acid and alkaline damage. The difference between damage in the presence or absence of electrolytes is due to the Donnan membrane effect. The internal fibre pH lags behind the bath pH in the absence of electrolytes.

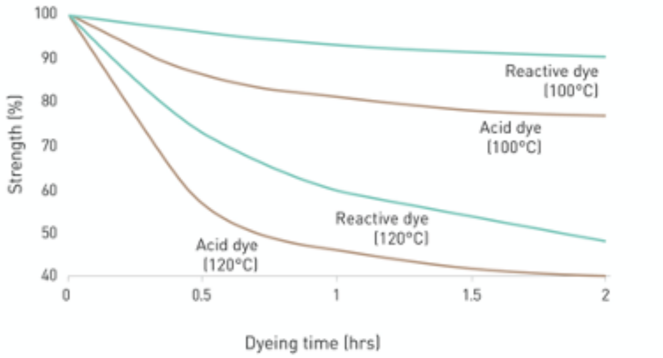
TEMPERATURE AND TIME OF DYEING

Lowering the temperature and reducing the time taken for the dying process:

- reduces the permanent set imparted
- reduces chemical damage to the fibre.

This can result in poorer dyeing outcomes in other areas, including:

- ring dyeing
- poorer wet fastness
- poorer rub fastness
- incomplete exhaustion
- potential unlevelness of levelling acid dyes.



The impact of dyeing time, temperature and dye type on fibre strength

9 - **Module 6:** Side effects of dyeing

INDICATE THAT it has been known for many years that damage during dyeing can be reduced by:

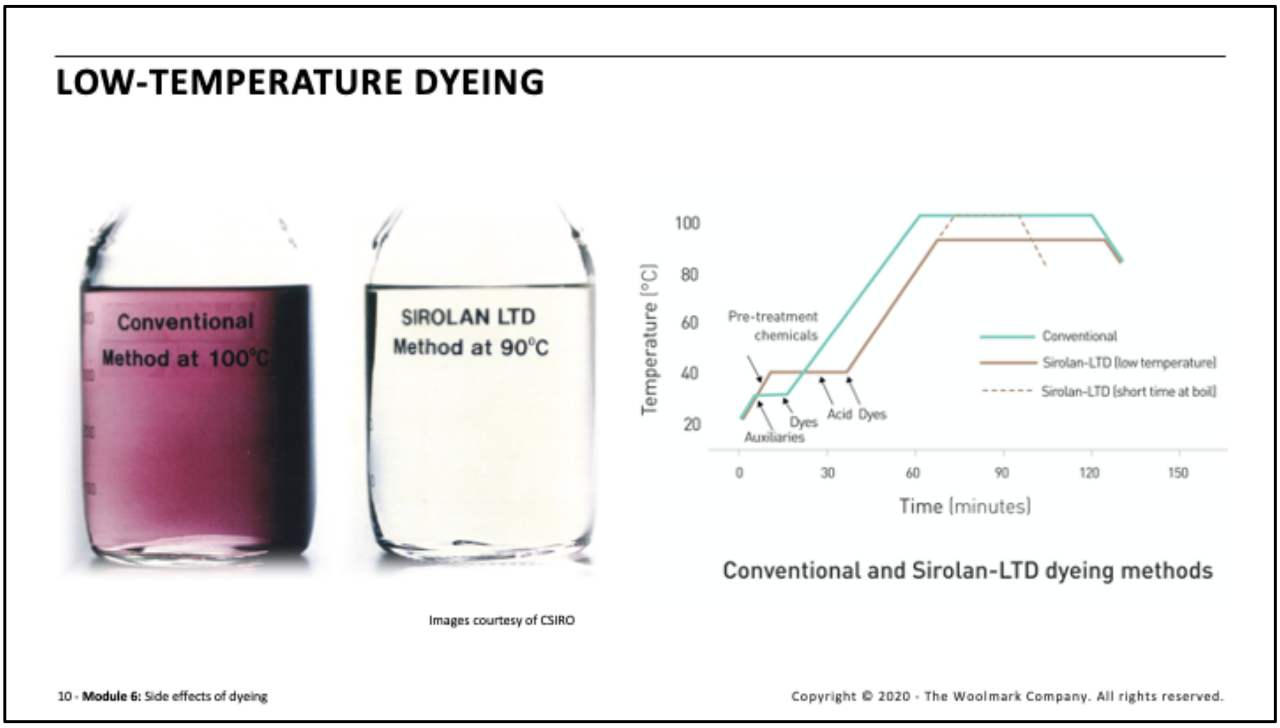
- reducing the temperature of dyeing
- reducing the time of dyeing.

EXPLAIN THAT both these actions have the effect of:

- reducing the amount of permanent set imparted during dyeing
- reducing hydrolysis of the macromolecular chains
- reducing chemical changes in sensitive side chains (e.g. tryptophan).

NOTE THAT the challenge with this approach is that the lower migration rates at low temperatures promotes other issues including:

- ring dyeing
- poorer wet fastness
- poorer rub fastness
- incomplete exhaustion
- potential unlevelness of levelling acid dyes.



NOTE THAT special auxiliaries can be used to dye wool at low temperatures.

Amphoteric ethoxylated hydroxysulphobetaine is used to pre-treat the wool. This auxiliary is thought to:

- modify the non-keratinous regions at the scale edges and inside the fibre
- remove labile lipid material (Small amounts of lipid and non-keratinous proteins are removed during this pre-treatment.).

An example of such an auxiliary is Valsol NTA-N from APS Chemicals formerly called Sirolan LTD.

EXPLAIN THAT the treated wool has improved dyeing properties, showing increased rates of dye exhaustion and diffusion into the fibre. It can be dyed to a satisfactory standard at 85–90'C instead of at the boil, or alternatively, can be dyed for a shorter time at the boil.

MENTION THAT water-soluble organic solvents also increase the rate of dyeing, but are rarely used for environmental reasons.

POINT OUT that polyethoxylated alkylphenols have also been shown to allow successful dyeing at lower temperatures.

Concerns about the toxicology of these auxiliaries mean that ethoxylate alcohols are now recommended alternatives.

NOTE: Low temperature dyeing is only applicable to a restricted range of dyes due to problems of compatibility.

LOW-TEMPERATURE-DYED PRODUCT

IMPACT ON WEAVING YARN (2/64NM) DYED AT HIGH AND LOW TEMPERATURES		
	Conventional temperature	Low temperature
Temperature (ºC)	104	90
Time (minutes)	40	60
Yarn strength (cN)	217	232
Yarn elongation at break (%)	11.2	13.1
Weft stops/1000 picks	0.44	0.16
Warp stops/1000 picks	0.68	0.25
Overall weaving efficiency (%)	90.9	97.8

IMPROVEMENT COMPARED WITH WOOL DYED AT THE BOIL (%)			
	Worsted top	Woollen loose	Semi-worsted
Count (tex)	38	150	350
End-breaks/1000 spindle hours	25	86	81
Yarn tenacity (cN/Tex)	4	13	12
Yarn elongation at break (%)	17	14	12
Overall yield (g)		6	2
Weaving efficiency (%)	10		

11 - **Module 6:** Side effects of dyeing

REFER participants to the table on the right-hand side of the slide which shows the impact of low temperature dyeing with Valsol NTA-N on the properties and performance of:

- worsted top
- loose carding wool
- loose semi-worsted type wool.

INDICATE THAT it can be seen that there were improvements across all parameters:

- end-breaks/1000 spindle hours
- yarn tenacity
- yarn elongation at break
- overall yield
- weaving efficiency in the case of worsted production.

EXPLAIN THAT the table on the left-hand side compares conventional and low-temperature dyeing on a 2/64Nm weaving yarn dyed with a mixture of Lanacron and Lanaset dyes.

NOTE THAT all aspects of yarn performance were improved by dyeing at a lower temperature in the presence of Valsol NTA-N.

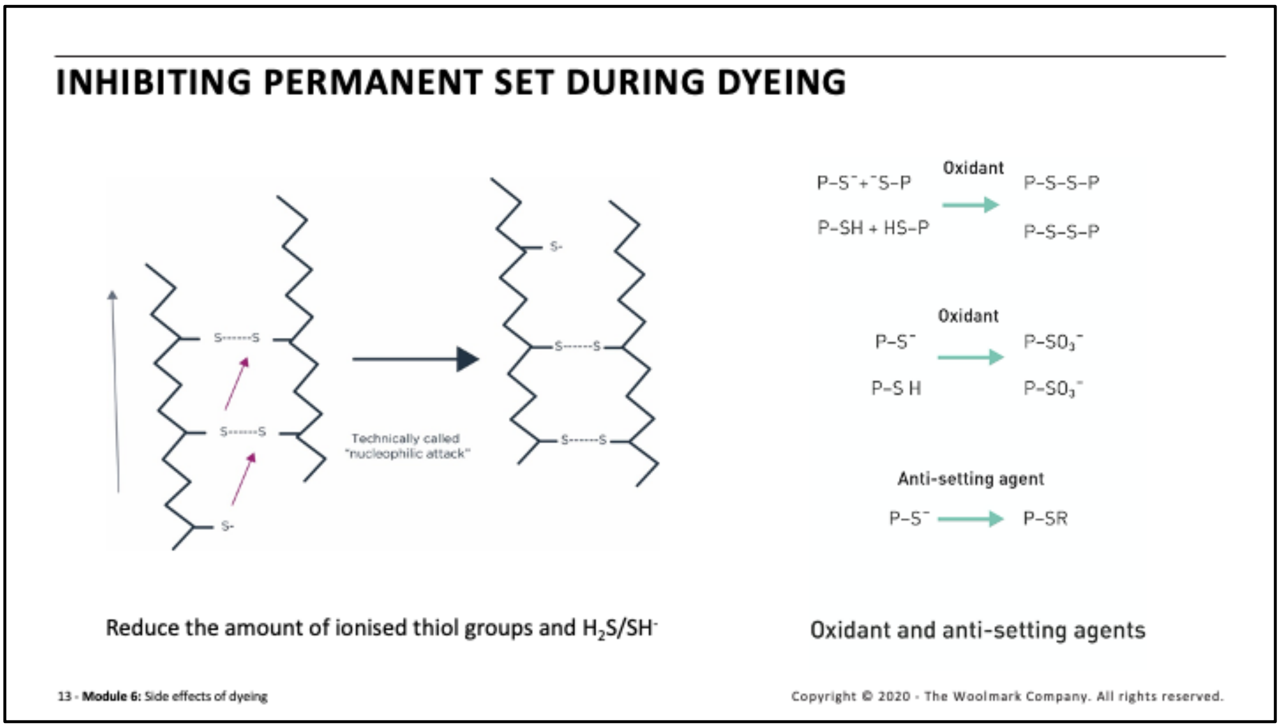
LOW-TEMPERATURE-DYED YARN

	DYE FASTNESS			PHYSICAL PROPERTIES			
	Alkaline wet	Rubbing dry	Rubbing wet	Tenacity (cN/tex)	Elongation at break	Work to break	Colour difference
Ecru				7.1	15.0	1081	
Conventional 60min at 100°C	4	4–5	3–4	6.2	10.2	638	
Low temperature 20min 100 – Valsol LTD	4	4–5	3–4	6.7	11.3	765	0.4

12 - **Module 6:** Side effects of dyeing

EXPLAIN THAT the data in this slide compares yarn dyed at the boil for a conventional time (60mins) with yarn dyed using a low temperature dyeing auxiliary for a shorter time (20mins) at the boil.

NOTE THAT the reduction in damage from the use of an auxiliary and a short time of boiling did not affect the dye fastness and there was no significant difference in the final colour.



EXPLAIN THAT anti-setting technology to minimise permanent setting during dyeing was commercially introduced during the mid 1990s.

Two methods have been used:

- inclusion of oxidants in the dyebath, which remove free thiol groups
- inclusion of substantive electrophilic compounds, which react with free thiol groups.

INDICATE THAT currently-available technology relies on the addition of:

- a hydrogen peroxide activator and a small quantity of hydrogen peroxide to the dyebath
- addition of maleic anhydride or a maleic acid ester to the dyebath

The auxiliary and/or hydrogen peroxide are added at the start of dyeing and the process then carried out as normal. Peroxide can only be used with dyes that are not sensitive to oxidation

NOTE THAT both products reduce the number of free (ionised) thiol groups in the fibre and thus the rate of permanent setting.

POINT OUT that formaldehyde also reacts with free thiols, so formaldehyde release agents can also reduce permanent setting. The use of this reagent is limited for health reasons.

MENTION THAT high levels (>3.0%) of reactive dyes have good anti-setting properties because they react with free thiols. Anti-setting agents are therefore unnecessary with these dyes.

ANTI-SETTING AGENTS AND DAMAGE DUIRNG DYEING

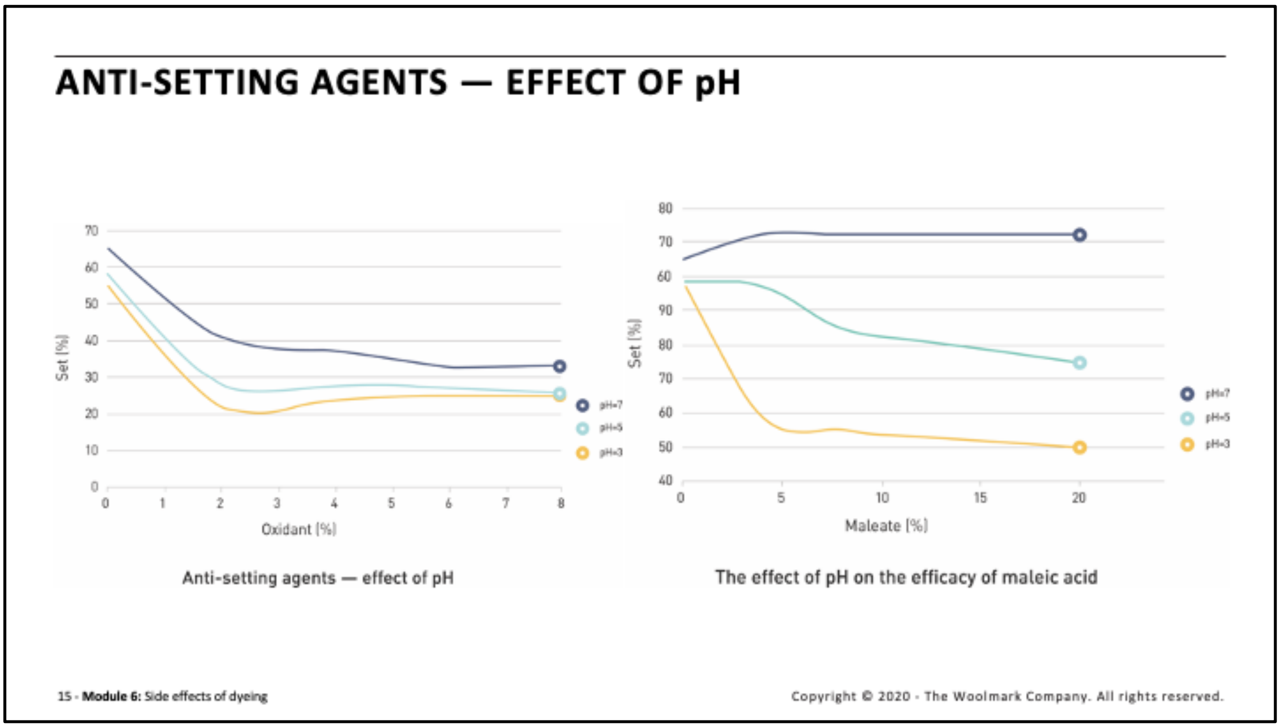
FIBRE/YARN PROPERTY	UNDYED	CONTROL	BASOLAN AS
Tenacity (g/tex) (fibre)	9.86	7.30	8.82
Extension (%) (fibre)	50.2	38.2	43.3
Strength (cN) (yarn)		255	291
Extension (%) (yarn)		12.2	19.0

14 - **Module 6:** Side effects of dyeing

EXPLAIN THAT a number of industrial trials have been performed with Basolan AS. The results of one such trial is shown in the table above. In this trial the wool was dyed in fibre form and spun to yarn. The number of end-breaks in spinning after dyeing with and without the anti-setting agent (Basolan AS) was reduced. Increases in yarn tenacity and extension also were observed.

NOTE THAT in separate trials not shown the number of spinning breaks was reduced by:

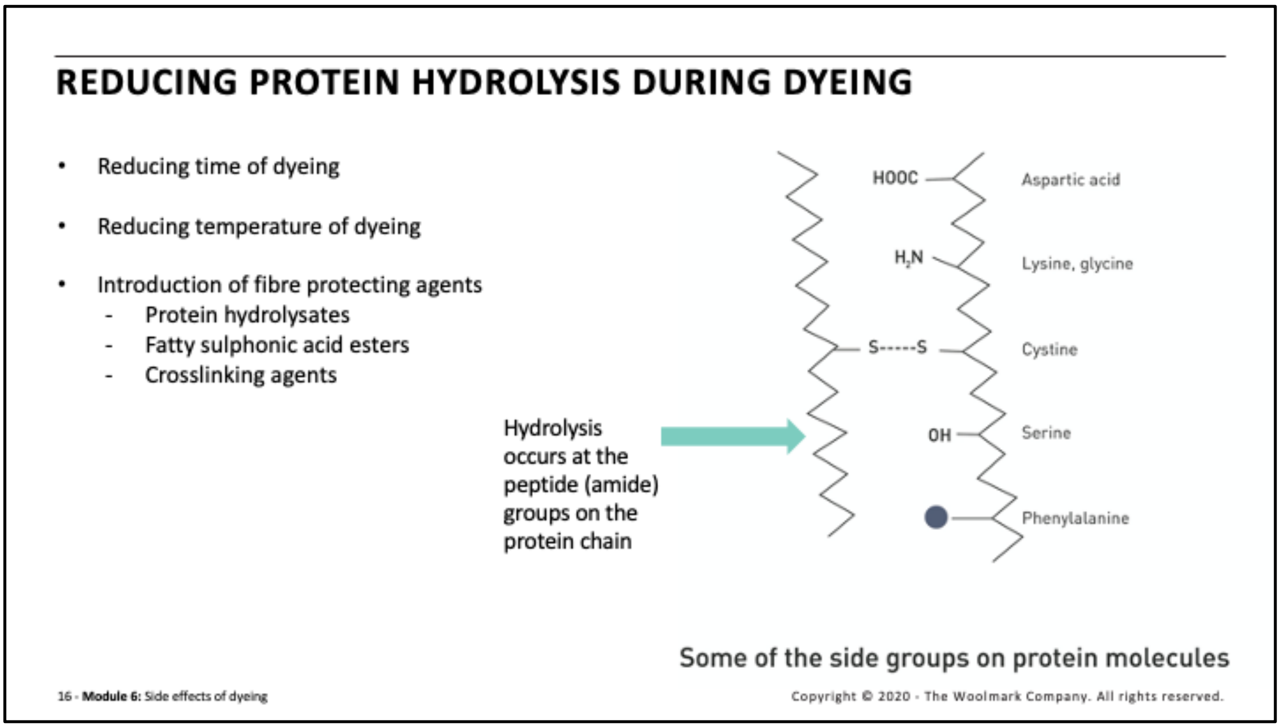
- 17% for a lamb's wool batch
- 30% for a Shetland batch.



NOTE THAT the effectiveness of the oxidative anti-setting agent is relatively unaffected by pH (as illustrated by the left-hand graph on the slide).

POINT OUT that on the other hand, the effectiveness of the electrophilic compound, maleic acid — which removes free thiols, is affected by pH (as illustrated by the right-hand graph on the slide).

- At pH=3 maleic acid has substantivity and it is effective in reducing permanent setting during dyeing
- At pH=7 maleic acid has little substantivity and it is ineffective.



EXPLAIN THAT the hydrolysis of wool proteins can be reduced in a number of ways:

- By reducing the time and temperature of dyeing.
- Protein hydrolysates (from other protein sources) can be introduced that, it is claimed, will degrade sacrificially instead of the wool fibre.
- Certain surfactant products can be included that slowly release formaldehyde to cross-link and stabilise the wool protein chains.

MENTION THAT protein hydrolysates has been used successfully when dyeing severely weathered or otherwise damaged fibres. It can also be beneficial in reducing hydrolytic damage if the wool has to be re-dyed.

NOTE THAT inclusion of alkylsulphonic acid esters also reduces damage. They are claimed to adhere to the fibre surface.

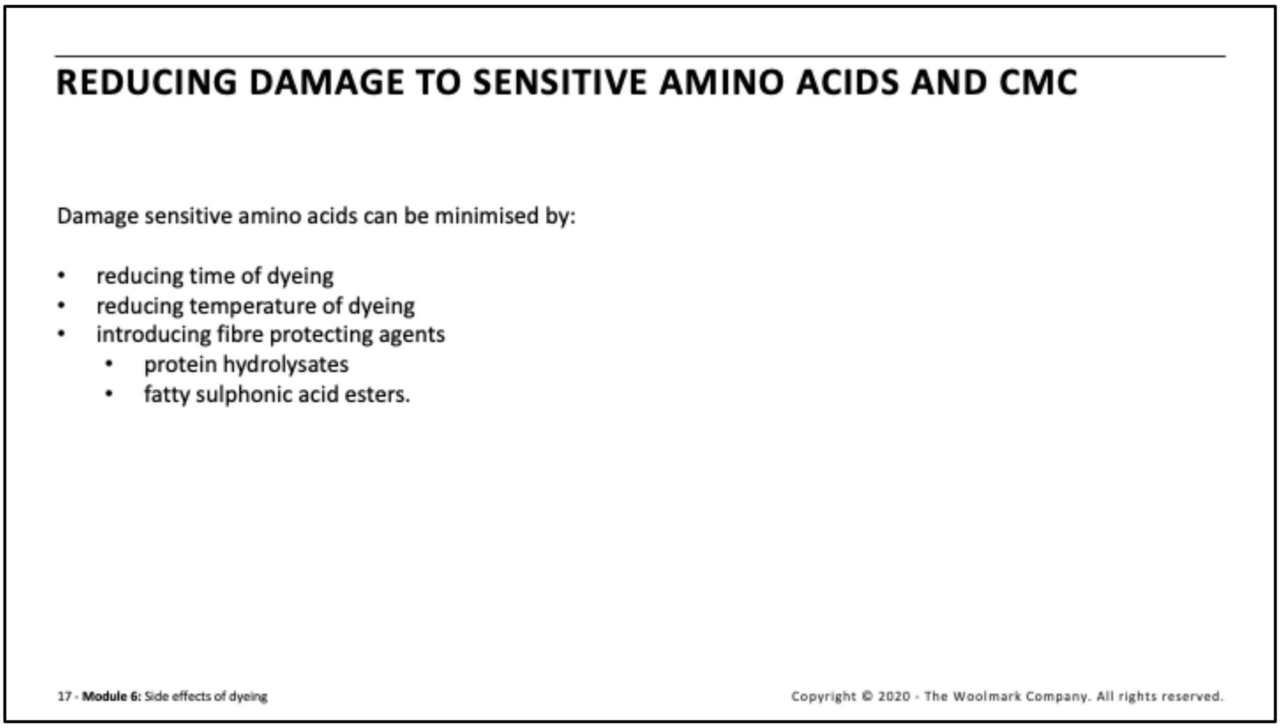
EXPLAIN THAT formaldehyde introduces cross-links in wool which:

- reduces weight loss in dyeing
- can maintain fibre tenacity,
- extensibility may be reduced.

INDICATE THAT products that slowly generate formaldehyde during dyeing are most effective when utilised in dyeing at high temperature (above 105°C)

- Hexamethylene diamine (hexamine)
- Lanasan PW (Clariant)
- Miralan HTW (Huntsman.)

Similar auxiliaries are available from other suppliers.



INDICATE THAT damage to sensitive amino acids can be minimised by:

- reducing the time and temperature of dyeing
- avoiding high pH during dyeing
- the use of wool-protecting agents, such as:
    - protein hydrolysates
    - fatty sulphonic acid esters.

SIDE EFFECTS OF DYEING — FABRIC OR 'PIECE' DYEING

Additional side effects of the dyeing process include:

- softer and 'fuller' fabric handle
- permanent setting of running marks
- cockling (uncontrolled relaxation of the fabric)
- facing up (hairiness on the fabric surface).

Running marks (creases in the warp direction) are caused by permanent setting during the dyeing process.

18 - **Module 6:** Side effects of dyeing

EXPLAIN THAT some of the other side effects of dyeing on fabric, dealt with earlier in this course, are:

- a softer and fuller handle fabric
- running marks in fabric (crease marks in the warp direction) caused by permanent setting of the unchanging folds in the fabric. This can be reduced by:
    - using anti-setting agent to inhibit permanent setting of the creases
    - ensuring the fabric can re-fold during rope dyeing
- cockling or 'crows feet' (uncontrolled relaxation of the fabric, arising from inadequate setting during fabric preparation — anti-setting agents have no effect on this type of distortion)
- facing up (hairiness caused by felting or abrasion on the metal parts of the machine — anti-setting agents have little or no effect on this issue).

SIDE EFFECTS OF DYEING — TIPPINESS AND SKITTERINESS

Tippiness of the wool fibre reflects the damaging effects of light and weather to the cuticle on tip as the fibre grows causing:

- the fibre to be more hydrophilic
- preferential adsorption of dyes

The rate and equilibrium dye uptake can also be affected.

Tippiness and 'skitteriness' are terms that reflect differences in colour or depth of the shade between different parts of the fibre (e.g. root and tip)
and between different fibres.

A problem with some milling and reactive dyes dyes.

Control — skittery or 'tippy' dyeings are usually avoided by using suitable levelling agents.

19 - **Module 6:** Side effects of dyeing

EXPLAIN THAT tippiness refers to the damage to the fibre from light and weather as it grows on the animal. Weathering and UV light damages the cuticle cells on the tip of the fibre, making it more hydrophilic, leading to preferential adsorption of dyes. Both rate of strike and equilibrium dye uptake can also be affected.

POINT OUT that 'skitteriness' is a term used to describe differences in the colour and depth of the shade between and within fibres.

NOTE THAT skittery or tippy dyeings lack a 'solidity' in the shade.

This issue can be seen with some milling and reactive dyes.

MENTION THAT skittery or 'tippy' dyeings are usually avoided by using suitable levelling agents.

INDICATE THAT polyethoxylated cationic or amphoteric auxiliaries are used to improve levelness. Examples of these products include:

- Albegal A and B and SET (Huntsman)
- Uniperol SE (BASF)
- Lyogen SU and ULN (Clariant)

NOTE: The use of too much levelling agent can affect exhaustion of the dye.

OTHER EFFECTS OF PERMANENT SETTING

YARN	STRENGTH (cN)	EXTENSION (%)	BULK (cm^3/g)	
			After dyeing	After dyeing and steaming
Control	383.9	9.9	8.1	13.0
Basolan AS	346.2	12.3	8.7	14.3
Hank-dyed	363.5	12.3	10.9	14.3

NOTE: Control and Basolan AS treatments are package dyed.

20 - **Module 6:** Side effects of dyeing

EXPLAIN THAT the use of anti-setting technology to reduce permanent set in wool during dyeing has other benefits for the wool product as illustrated on the slide.

A knitting yarn was package dyed with Basolan AS and without (control). The same yarn was also hank-dyed. The bulk of the yarns were measured after dyeing and after subsequent steam relaxation. The outcomes were as follows:

- The yarn that was package dyeing using Basolan AS (an oxidising system) had greater yarn bulk than that dyed in the absence of the anti-setting agent (control).
- Although both the package-dyed yarns had less bulk than hank-dyed yarn, there was still a significant increase in bulk over the yarn dyed without the anti-setting agent (control).

NOTE THAT after the yarn was steam relaxed the difference between the bulk of the hank-dyed yarn and the package dyed with the anti-setting agent was small.

INDICATE THAT the implication is that the use of an anti-setting agent could allow the package dyeing of a broader range of machine-knitting yarns without significant loss of bulk.

OTHER EFFECTS OF PERMANENT SETTING

FABRIC	DYES	HYGRAL EXPANSION (%)			
		Control		Basolan AS	
		Warp	Weft	Warp	Weft
Crespino	1:2 Metal complex	3.32	3.63	2.72	3.01
Sirofil	Milling	5.37	4.12	2.58	2.84
Sirofil	Afterchrome	5.4	4.64	4.63	3.62
Gabardine (A)	Milling	3.6	8.18	2.56	4.57
Gabardine (A)	Afterchrome	6.41	3.74	4.99	3.12

21 - **Module 6:** Side effects of dyeing

EXPLAIN THAT there is normally an increase in hygral expansion (the growth of a fabric as the fibres adsorb moisture) in wool fabric as a result of piece dyeing. This can cause problems in garment appearance when structured wool garments are worn in a humid environment.

INDICATE THAT anti-setting agents, such as Basolan AS, reduce the increase in hygral expansion of fabric during dyeing. As illustrated on the slide, the benefits are greatest for fabrics with a high level of weave crimp in either warp (e.g. gabardine) or weft direction.

NOTE THAT high levels of fabric permanent setting before (crabbing) and/or after dyeing (decatising) may negate these benefits by themselves, imparting high levels of hygral expansion.

Both the finishing and dyeing operations must be optimised to ensure the best results.

POINT OUT that there is little difference in handle for a finished fabric that has been dyed with Basolan AS, and one that has been dyed conventionally. Basolan AS-dyed fabric has been judged to have a handle more akin to a top-dyed fabric than a piece-dyed fabric.

EXPLAIN THAT conventionally-dyed wool is easier to re-set than wool that has been dyed using the Basolan AS Process. Levels of permanent set lower than normal have been measured as a result of pressure decatising Basolan AS-dyed fabric. However, this reduced ability to re-set dyed fabric has not caused any problems as a result of the industrial trials.

COMPROMISES IN DYEING

	MINIMUM DAMAGE	LEVELLING DYES	MILLING DYES	REACTIVE	CHROME
pH	4.5	~3	~7	6-7	3.5
Time	Short	Longer to level	Longer to exhaust evenly		Long process dye and chroming
Temperature (°C)	~90	100	100	100	
Additives	Protective	Not used	Not used	Inherently protective	Not used

22 - **Module 6:** Side effects of dyeing

NOTE THAT often during dyeing the conditions for optimum application of dyes and fastness differ from those of the conditions to minimise damage.

EXPLAIN THAT the slide compares the optimum conditions for minimising damage with those for optimised dyeing. The first column indicates the conditions that would minimise damage. The other columns indicate 'normal' dyeing conditions for various dye types. The actual conditions are not always compatible with minimum damage.

INDICATE THAT examples of compromises involved include:

- higher temperature gives improved migration but increases damage
- lower pH can improve exhaustion and strike rate, but can impair levelness
- larger-molecule dyes have higher wet fastness but are more difficult to dye evenly.

SUMMARY — MODULE 6

The major side effect of dyeing is fibre damage

Fibre damage is caused by:
- hydrolysis of the protein
- permanent setting of the fibre
- degradation of specific amino-acids.

Depending on the form of the wool, damage in dyeing is seen as:
- reduced fibre length after combing
- reduced spinning efficiency
- reduced yarn tenacity
- reduced winding and warping efficiency
- reduced weaving and knitting efficiency
- reduced fabric tensile and tear strength
- reduced abrasion resistance
- yellowing of the fibre.

Damage is reduced by:
- dyeing at reduced temperature
- dyeing for a shorter time
- control of pH to near the iso-electric point
- inclusion of soluble protein material
- inclusion of an anti-setting agent
- use of cross-linking agents.

Other effects of dyeing include:
- a softer and fuller handle
- running marks in fabric
- increased yarn bulk
- cockling or crows feet
- facing up skitteriness
- increased hygral expansion in fabric.

SUMMARISE this module by explaining that often during dyeing the conditions for optimum application of dyes and fastness differ from those of the conditions to minimise damage.

REMIND participants that the slide compares the optimum conditions for minimising damage with those for optimised dyeing. The first column indicates the conditions that would minimise damage. The other columns indicate 'normal' dyeing conditions for various dye types. The actual conditions are not always compatible with minimum damage.

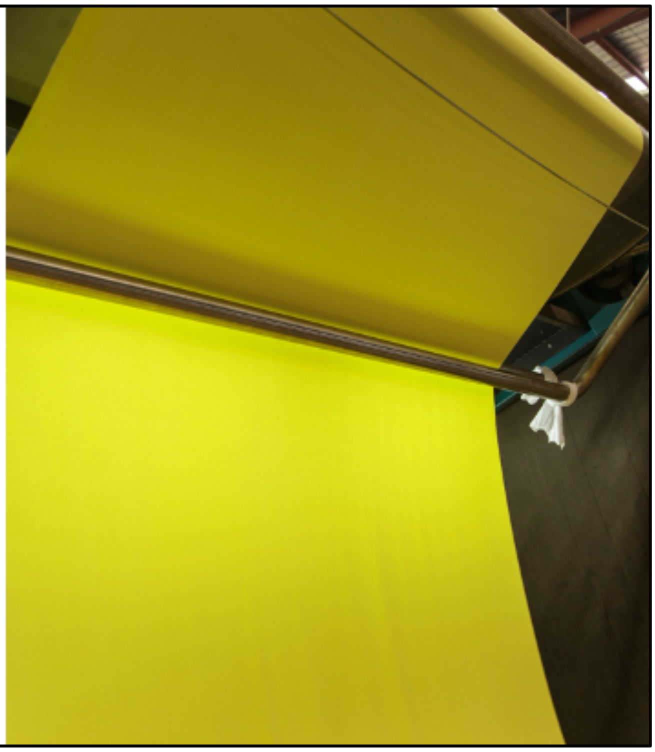
REVIEW examples of compromises involved include:
- higher temperature gives improved migration but increases damage
- lower pH can improve exhaustion and strike rate but can impaired levelness
- larger-molecule dyes have higher wet fastness but are more difficult to dye evenly.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*

THE WOOLMARK COMPANY

THANK YOU



INFORM participants of the time and location for the next lecture — *Module 7 Dyeing of wool blends*— and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

MODULE 7

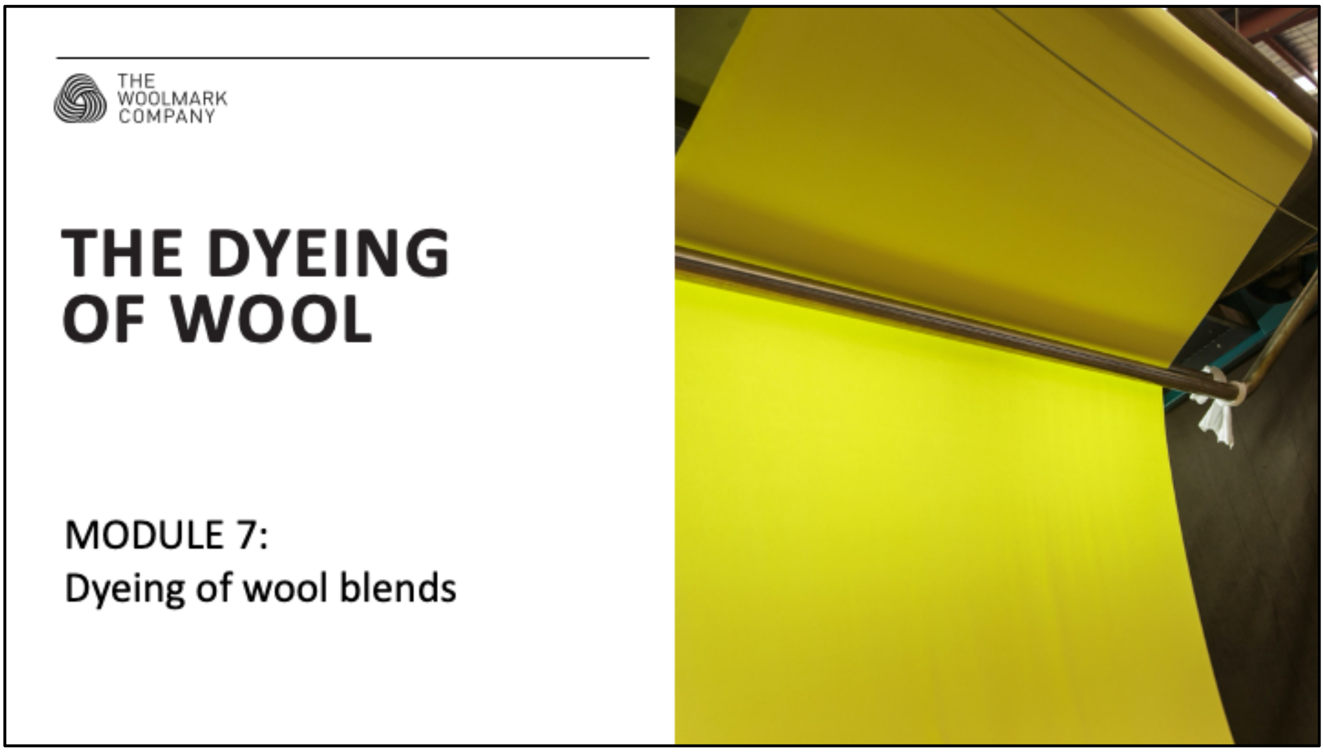
THE WOOLMARK COMPANY

DYEING OF WOOL BLENDS

RESOURCES — MODULE 7: DYEING OF WOOL BLENDS

Contained in *The dyeing of wool* Demonstration kit you will find the following resources for use as you deliver **Module 7: Dyeing of wool blends**:

- wool polyester fabric — wool dyed only (fibre mixture)
- wool polyester fabric — wool dyed only (stripe)
- wool polyester — both dyed
- wool — cotton denim samples
- cotton denim samples



WELCOME participants to Module 7 of the Woolmark Wool Science, Technology and Design Education Program — *The dyeing of wool — Dyeing of wool blends.*

EXPLAIN THAT this module will review the reasons for blending wool with other fibres and the differences between the chemistry of commonly-blended fibres (both synthetic and natural). The module will then describe the impact of the different fibre chemistry on the blend dyeing process.

NOTE THAT there are three main reasons for blending wool with other fibres:

- changes in the aesthetics of wool garments
- enhanced physical properties
- increased affordability and market share.

Aesthetics
The appearance of the fabric can be improved by the use of blends. Examples of these improvements include:

- differences in lustre (e.g. in wool/rayon)
- the ability to achieve multi-coloured fabrics in a single dyeing operation
- a change in handle (feel)
- new casual looks (e.g. wool-cotton in shirts, denim).

Physical properties
Polyester and nylon can contribute strength to a wool blend.
Polyester can impart easy-care characteristics to fabrics and garments.

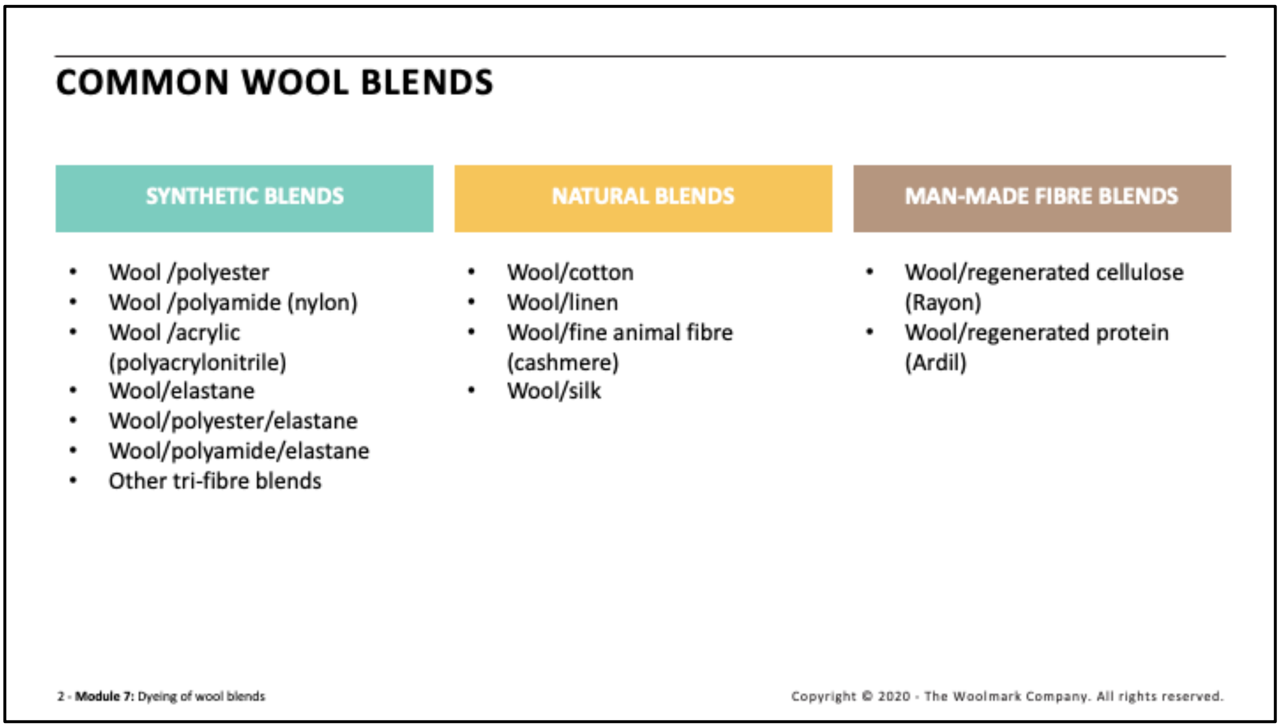
Price considerations
The partial replacement of wool with a less expensive fibre can reduce the cost of the products to the consumer, increasing the size of the market for the fabric.

INFORM participants that by the end of this module they will be able to:

- outline the key differences in chemistry of the fibres commonly blended with wool
- outline the impact of these differences in chemistry to the blend dyeing process
- describe the different approaches taken to dye common wool blends.

RESOURCES REQUIRED FOR THIS MODULE

- *wool/polyester fabric — wool dyed only (fibre mixture)*
- *wool/polyester fabric — wool dyed only (stripe)*
- *wool/polyester — both dyed*
- *wool /cotton denim samples*
- *cotton denim samples*



EXPLAIN THAT wool can be blended with a range of synthetic, natural and man-made fibres. The most common wool blends are shown on the slide and the reasons for these blends are outlined below.

Polyester/wool blends
The primary reason for blending polyester with wool is to reduce the cost of the retail product. Blends containing 20%, 30%, 40%, 55% and 75% polyester are widely used commercially.

NOTE THAT blending with polyester also can improve the durability of the fabric. The tear strength and abrasion resistance of the resulting fabric are normally higher than the equivalent pure wool fabric.

MENTION THAT blending with polyester can prevent felting and improve smooth drying, thereby improving the easy-care performance.

Wool/polyamide
Polyamide (nylon) is normally blended with wool to increase strength and reduce cost.
The blend generally occurs in machine and hand knitting as well as carpet yarns, and sometimes in stretch apparel fabrics.

Acrylic (polyacrylonitrile)/ wool
These blends are widely used in knitwear and soft furnishings to reduce cost and add to the colour range.

Wool/elastane blends
Blends containing a combination of wool and elastane are used to impart stretch characteristics to wool products, such as activewear.

Wool/natural fibres
Blends of wool with other natural fibres are usually used to add value by imparting different aesthetics to the product (handle and appearance).

Wool/man-made fibres
Blends of wool with man-made fibres, such as Rayon are also normally used to impart new aesthetics (appearance and handle) to fabrics.

HAND OUT *samples of wool/polyester samples.*

ASK *participants for comments on handle (feel) of the samples.*

ACKNOWLEDGE *responses.*

SYNTHETIC FIBRES — CHEMISTRY AND STRUCTURE

Polyester
- Derived from glycol and terephthalic acid.

Polyamide
- Derived from 1,6 hexandiol and adipic acid.
- Derived from caprolactam.

Acrylics
- Co-polymers of acrylonitrile.

Elastane
- Derived (primarily) from polyurethane
- Usually in filament form.

Fibre chemistry affects:
- type and number of dye sites
- fibre glass transition temperature
- swelling in water (ease of dye migration).

Key structural properties impacting wool/synthetic blends:
- fibre diameter (i.e. fineness)
- surface properties
- cross section
- delustering
- Texturing.

3 - **Module 7:** Dyeing of wool blends

INDICATE THAT the chemistry of the synthetic fibres used in a range of wool blends varies, which impacts the way the various blends are managed.

Fibre chemistry affects:
- the type and number of dye sites
- the glass transition temperature of the fibre
- swelling in water (i.e. ease of migration of the dye into the fibre).

EXPLAIN THAT polyester is a polymer derived from glycol and terephthalic acid. Co-polymers have been developed to make the fibre dyeable at lower temperatures or with alternate dye types (e.g. cationic dyes).

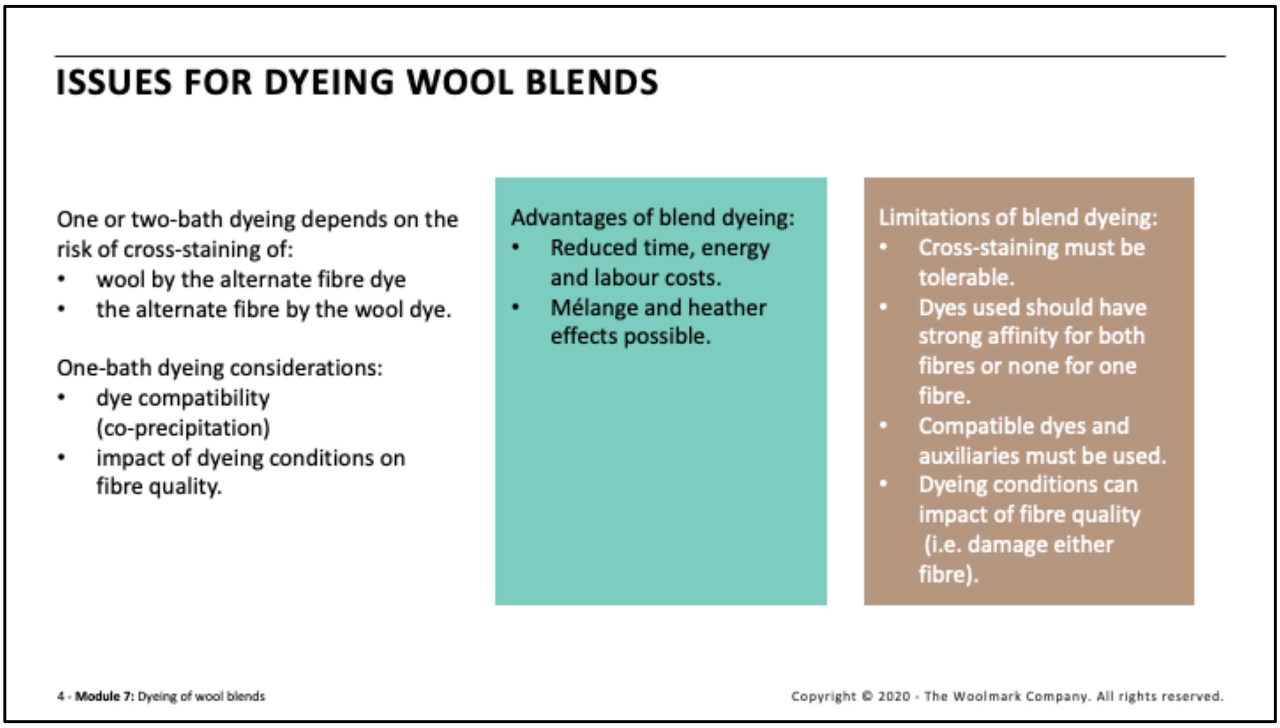
POINT OUT that polyamide (often referred to as nylon) is derived from 1,6 hexandiol and adipic acid or from caprolactam. Polyamide has superficial chemical similarities with wool in that both are polyamides (meaning they both contain macromolecules with repeating courses linked by amide bonds) but quite different structure and physical properties.

INDICATE THAT acrylics are co-polymers of acrylonitrile. The nature of the additional monomers included to modify physical and/or dyeing properties varies with the acrylic type.

Elastane is a generic term for polyurethane filaments (e.g. Lycra) noted for their high stretch and excellent recovery properties.

EXPLAIN THAT in addition to differences based on chemical composition, there are structural differences within and between the synthetic fibre groups including:
- the fibre diameter (i.e. fineness — measured in dtex)
- fibre surface properties
- cross-section (round, trilobal, etc.)
- degree of delustering,
- texturing
- the nature of any aftertreatment applied to the fibre

NOTE THAT all of the above factors influence the colouration of the fibre and the dyeing of the blend.



INDICATE THAT dyeing systems for blends fall into two main categories:

- The same dye (s) can be used for both fibres.
- Different dyes must be used for each fibre.

The extent to which the dyes for one fibre exhaust onto the other fibre is called cross-staining.

If the cross-staining is fast, the dye can be left on the fibre. If the cross-staining is not fast, it must be prevented or the unwanted dye removed from the stained fibre.

Cross-staining can be limited, or prevented, by the use of:

- dyebath auxiliaries (e.g. dye-site blocking agents)
- two-bath dyeing methods rather than one-bath methods.

EXPLAIN THAT there are advantages in time, energy and labour costs if a blend can be dyed in a single bath. This requires:

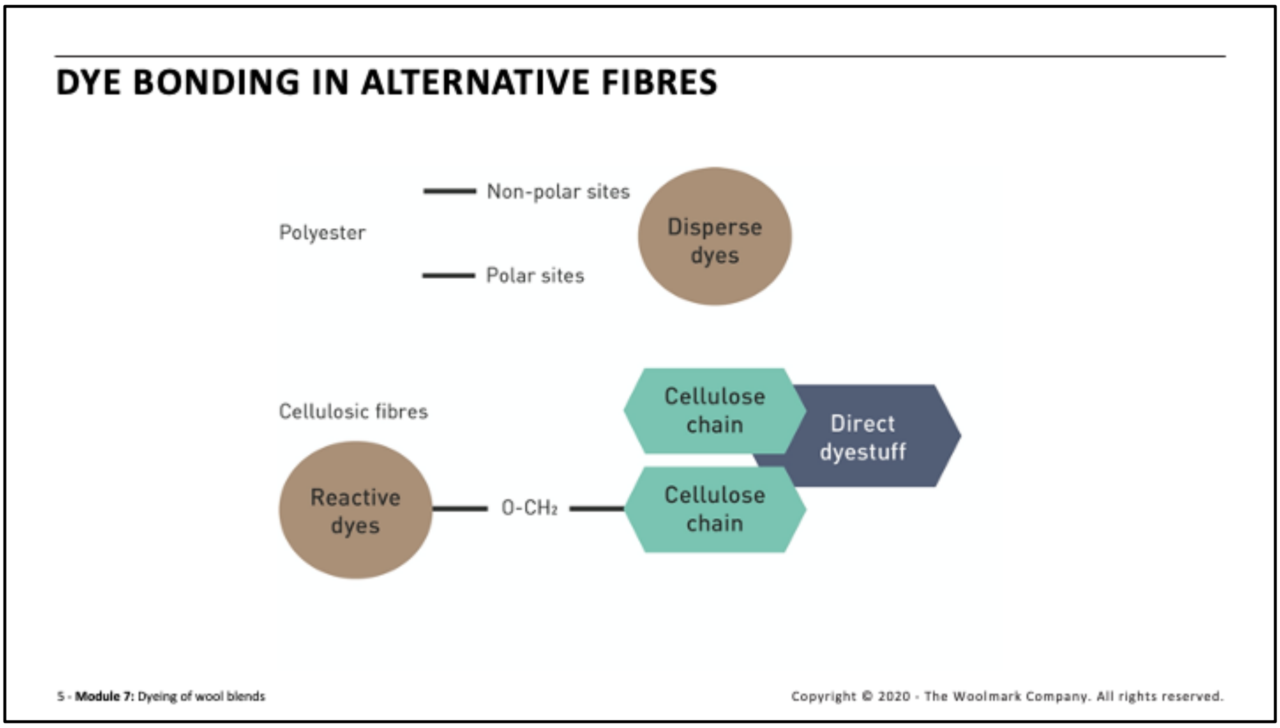
- the dyes used to have affinity for both fibres and give reasonably solid shades.
- the components of the dyebath to be compatible (with other and the fibres to be dyed)
- any cross staining which occurs to be tolerable.

POINT OUT that if dyes of opposite ionic charge are used in the same bath (e.g. anionic dyes for wool, cationic dyes for acrylic), co-precipitation (dye falls out of solution) can occur. Auxiliaries must be added to prevent precipitate forming. Dispersing agents can control precipitation.

NOTE THAT if the conditions of dyeing for one fibre (e.g. high temperature, high or low pH) will damage the other fibre, protective agents must be used. This condition applies in both one bath or two-bath processes.

MENTION THAT the circumstances which require two (or more) baths to be used include:

- incompatible dyeing methods
- unacceptable cross-staining that cannot be removed.

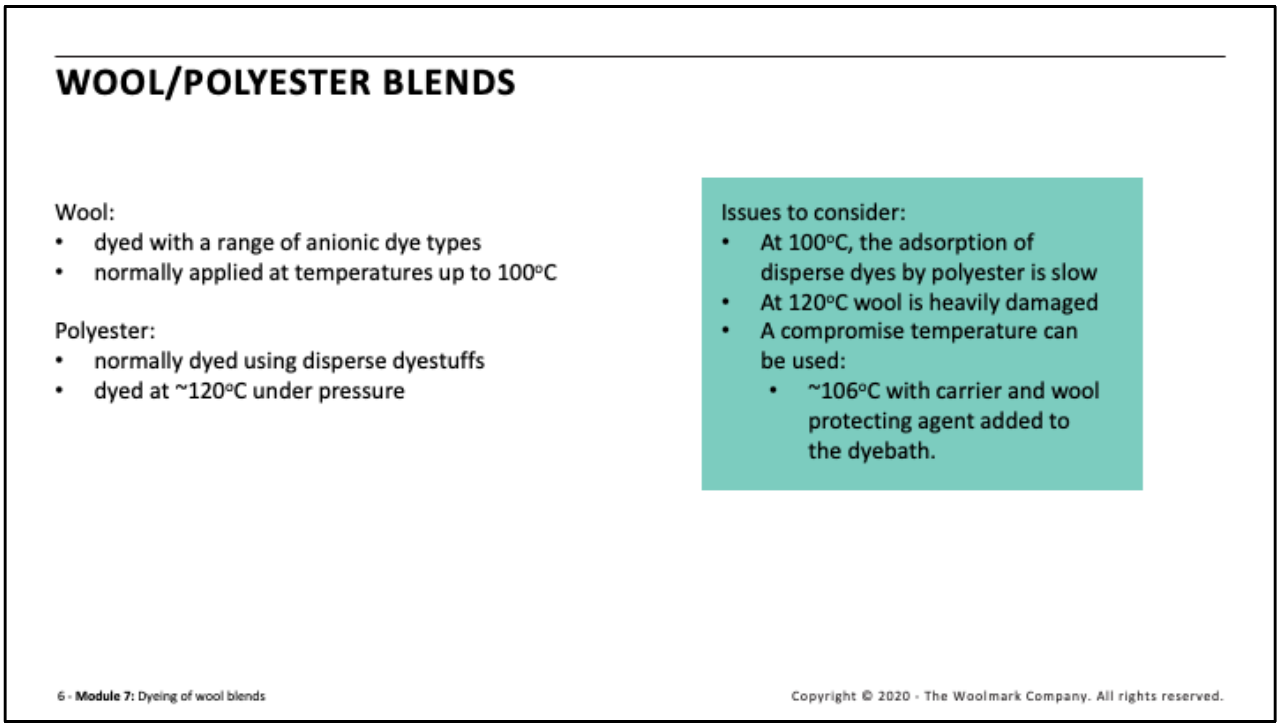


EXPLAIN THAT the bonding of alternative dyestuffs to other non-protein fibres has features in common with wool and also has some differences.

INDICATE THAT highly non-polar disperse dyestuffs bond weakly with non-polar sites in wool fibres. Such dyes will stain wool, but the bonding is too weak to achieve a fast dyeing. On polyester, the rate of migration of the dye at temperatures below 60ºC is so slow that, when applied under normal conditions, disperse dyes will not migrate out of the fibre during laundering.

NOTE THAT direct dyes have an affinity for cellulosic fibres and are held in these fibres by polar interaction. On the other hand, they have little affinity for wool.

EXPLAIN THAT reactive dyes react with nucleophilic groups in both wool and cotton. The dyes and their reactive groups differ between wool reactive and cotton reactive dyes to allow for the different nucleophilic groups in wool and cotton. In wool the dye sites are mostly amino groups whereas in cotton the dye sites are mostly hydroxy groups.



EXPLAIN THAT in fibre form wool and polyester are dyed separately, thus avoiding the disadvantages of blend dyeing. In yarn or fabric form the decision on whether a one-bath or two-bath method is most appropriate depends on the dyeing system used.

INDICATE THAT there are a number of methods by which wool/polyester blends can be dyed. It should be noted that:

- wool is normally dyed with anionic dyes at about 100ºC
- polyester is normally dyed with disperse dyes at 120ºC (under pressure).

At 100ºC the adsorption of disperse dyes by polyester is slow. As such, a diffusion accelerant (carrier) is needed if the dyeing requirements of the wool are to be accommodated in a one-bath system.

On the other hand, at 120ºC wool will be heavily damaged during the dyeing process, so a wool protecting agent will be needed if the dyeing temperature is increased to accommodate the requirements of the polyester.

NOTE THAT a compromise can be reached by using a one-bath systems and dyeing at about 106ºC with the addition of both a carrier and wool protecting agent. This process is outline in detail on the next slide.

POINT OUT that many dye manufacturers offer blended dye mixture products, which may be used successfully on wool/polyester blends. The Forosyn and Foroson SE ranges are mixtures of pre-metallised and disperse dyes and are applied from a single bath. These dyes are ideal for use on 45/55 wool/polyester blends, but can also be used on 60/40 wool rich blends — and for some 70/30 blends

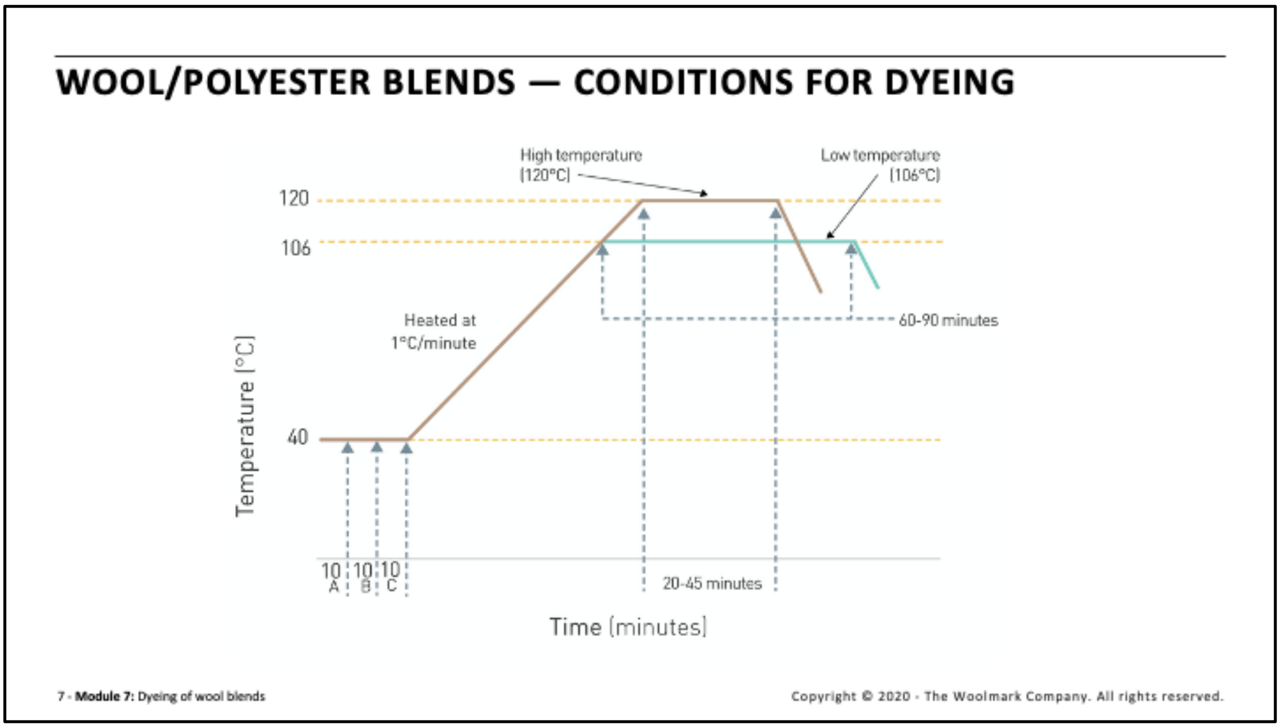
EXPLAIN THAT Lanaset dyes (wool dyes) can be combined with Terasil dyes (disperse dyes) at pH=4.5 to give optimum wool preservation. The dyes are stable at 120ºC and have excellent migration. TERASIL disperse dyes have good dispersion stability.

Disperse dye selection

The right selection of disperse dyes is essential for good results.

NOTE THAT the main criteria for the selection are:

- stability to reduction – the wash-off bath described on the next slide contains a reducing agent
- low cross-staining on wool.



Dyeing a wool/polyester blend at 106^{o}C
EXPLAIN THAT to achieve a successful dyeing result at 106^{o}C a diffusion accelerant (carrier) has to be used to achieve sufficient dye build-up on Polyester (UNIVADINE PB). The accelerants swell the polyester fibre allowing the dyes to penetrate and migrate through the fibre.

At dyeing temperatures below 120^{o}C the accelerant is necessary for most types of polyesters to achieve sufficient build-up. However, too much diffusion accelerant can cause blocking effects, depending on the polyester type.

Even at 120^{o}C, a carrier is recommended for dark shades (black and navy) to obtain better exhaustion and reproducibility on the polyester.

Dyeing a wool/polyester blend at 120^{o}C.
EXPLAIN THAT at 120^{o}C, disperse dyes show good build-up on polyester, but without protection, the wool fibre risks suffering significant damage during the dyeing process.

NOTE THAT wool quality can be preserved with a wool-protecting agent, such as MIRALAN HTP or IRGASOL HTW NEW (4%). The normal dyeing time is 45 minutes — the maximum time limit at 120^{o}C is 60 minutes.

REFER participants to the illustration on the slide which outlines a typical recipe for dyeing a wool/polyester blend in a one-bath system at both 106^{o}C and 120^{o}C.

Point A additions
- 0.5g/l CIBAFLOW CIR or ALBEGAL FFA
- 1g/l MIRALAN Q

Point B additions
- 0.5 % ALBEGAL SET
- 4 % IRGASOL HTW NEW or MIRALAN HTP
- 0–2g/l UNIVADINE PB
- 1g/l sodium acetate
- x % acetic acid 80% to pH 4.5

Point C additions
- y % LANASET dyes
- z % TERASIL dyes

NOTE: Where no value has been given for additions at points B and C these quantities will vary according to starting pH level of dyebath (x%) and depth of colour required (y% and z%).

POINT OUT that for very fine weaving yarns, a maximum dyeing temperature of 115^{o}C is recommended.

WOOL/POLYAMIDE (NYLON) BLENDS

- Wool and polyamide are somewhat chemically similar.
- Amino groups are the primary dye sites in both fibres.
- Both fibres can be dyed using the same dyes.
- Some acid and pre-metallised can be used on all wool/polyamide blends.

- Reactive dyes are rarely used for wool/polyamide blends.
- Mordant dyes are not used on polyamide
- Disperse dyes can be used for polyamide.

8

8 - **Module 7:** Dyeing of wool blends

INDICATE THAT the most common polyamide types are

- Polyamide 66 (Nylon 66)
- Polyamide 6 (Nylon 66), which has higher dye affinity than Polyamide 66 .

These blends are dyed using a number of different dyestuff classes.

NOTE THAT wool and polyamide are somewhat chemically similar. Amino groups are dyes sites in both fibres so they can be dyed by the same dyes.

Acid and pre-metallised dyes can be used in all wool/polyamide blends.

POINT OUT that reactive dyes are rarely used on wool/polyamide blends, but some of the latest developments in dyes and recipes allow their use in some shades.

Mordant dyes cannot be used on polyamide.

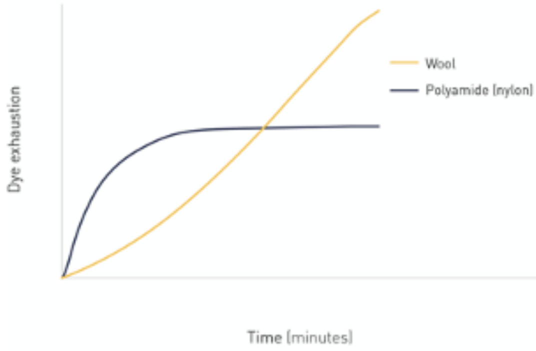
MENTION THAT disperse dyes can be used on polyamide, but are unsuitable for wool.

DYE UPTAKE BY WOOL AND POLYAMIDE (NYLON)

Wool and polyamide differ in two main ways:
- Kinetics — polyamide generally dyes faster than wool
- Saturation — Wool adsorbs more dye than polyamide.

Blocking agents are used in dyeing wool/polyamide blends to even out the rate of dye exhaustion on each fibre.

Blocking agents:
- are colourless anionic compounds
- have a high affinity for polyamide.
- exhaust rapidly onto the polyamide fibre, blocking dye sites
- allow dye to move onto the wool.



9 - **Module 7:** Dyeing of wool blends

EXPLAIN THAT although there are superficial similarities in the structure of wool and polyamide, the dyeing of these two fibres differs in two main ways:
- **Kinetics** — polyamide generally dyes faster than wool in the initial stages of dyeing (strike).
- **Saturation** — wool will adsorb much more dye than polyamide (i.e. wool has a greater number of dye sites).

INDICATE THAT blocking agents are normally used in dyeing wool blends. These agents are colourless anionic compounds with a high affinity for polyamide. They exhaust rapidly onto the polyamide fibre, blocking dye sites.

This evens out the rates in which the dye moves onto the components of blend.

The amount of blocking agent is adjusted so an even distribution can be achieved between the fibres.

NOTE THAT the required amount of blocking agent depends on:
- the dyes used
- dye concentration
- fibre type and blend ratio.

MENTION THAT the exact rates are determined in preliminary trials simulating bulk dyeing conditions.

Examples of blocking agents include:
- ERIONAL RF (Huntsman)
- CIBAFIX PAS (Ciba)

WOOL/POLYAMIDE (NYLON) BLEND — TYPICAL RECIPE

CHEMICALS/pH/TEMPERATURE	DYESTUFF GROUP		
	Sandolan E Nylsosan E	Sandolan MF Nylosan N	Sandolan Milling N Nylosan F
Blocking agent	Thiotan SRP liquid (0–6%)		
Levelling agent	Lyogen MF liquid (0.5–1%)		
Coverage of barré polyamide	Lyogen PN liquid or Sandogen CN liquid (1–2%)		
pH range (sodium acetate/acetic acid)	4.5–4.0	4.5–5.0	4.5-5.0
Dyeing temperature (°C)	85–95	90–98	95–98

10 - **Module 7:** Dyeing of wool blends

REFER participants to the slide showing typical dyeing recipes for wool/polyamide blends dyed with differing dye types to achieve different levels of fastness.

INDICATE THAT different types of dyestuffs are used to meet the wet fastness required. The pH range used allows for the differences in exhaustion and levelling rates.

WOOL/ACRYLIC BLENDS

Wool/acrylic blends are widely used in knitted textiles for:
- sportswear
- leisurewear
- men's and women's outerwear

These blends are often dyed in yarn form with a mixture of:
- acid or pre-metallised dyes
- basic dyes (e.g. Maxilon)

The main benefits of using these dyes are:
- a wide range of colours, including brilliant shades
- trichromatic systems are available
- good overall wet fastness
- usually good stability of the dyebath

The most important criteria for selecting basic (cationic) dyes are sensitivity to reduction and reservation of the wool.

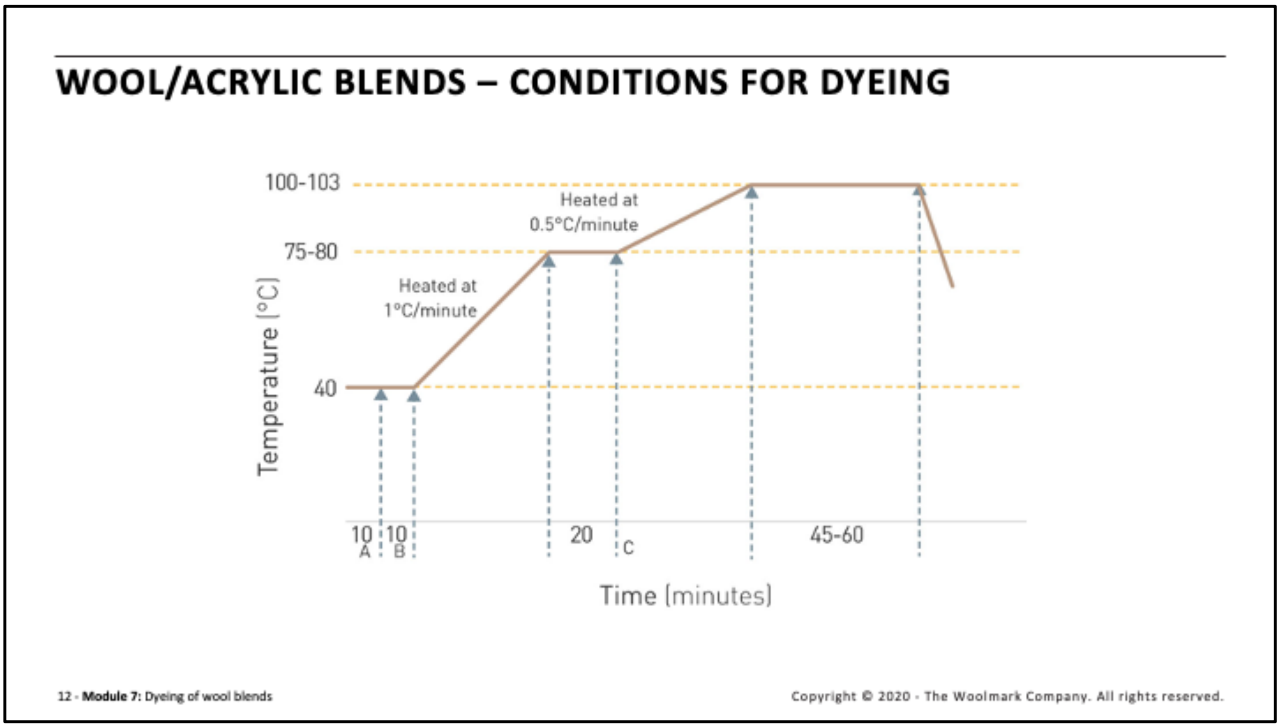
11 - **Module 7:** Dyeing of wool blends

EXPLAIN THAT wool/acrylic blends are widely used in knitted textiles for sportswear, leisurewear and men's and women's outerwear. These blends are often dyed in yarn form as packages or hanks.

INDICATE THAT the blend is dyed with a mixture of:
- acid or pre-metallised dyes for the wool component
- basic dyes (cationic dyes e.g. Maxilon) for the acrylic component.

MENTION THAT the main benefits of this dyeing system are:
- a wide range of colours, including brilliant shades
- trichromatic systems are available
- good overall wet fastness
- usually there is good stability of the dyebath.

NOTE THAT the most important criteria for selecting basic (cationic) dyes are
- sensitivity to reduction because a reductive wash-off is used after dyeing
- reservation of the wool. (avoiding cross-staining of wool by the basic dye).



INDICATE THAT a typical recipe for dyeing a wool/acrylic blend using Lanaset and Maxilon dyes is shown on the slide above:

Point A additions

- 0.5g/l CIBAFLOW CIR or ALBEGAL FFA
- 1g/l MIRALAN Q
- 0.5–1% ALBEGAL SET
- 0–3% Glauber's salt
- 1% sodium acetate
- pH 4.5 with acetic acid 80%

Point B additions

- y% LANASET dyes

Point C additions

- z % MAXILON dyes
- 0–1% TINEGAL MR NEW

NOTE: Where no value has been given for additions at points B and C these quantities will vary according to the depth of colour required (y% and z%).

INDICATE THAT the wet fastness of deep shades can be improved by washing off with 1 IRGASOL DAM (pH 4.5) for 20 minutes at 60–65°C followed by thorough rinsing.

Black shades

EXPLAIN THAT blacks are dyed in a two-bath process, dyeing first the acrylic fibre and subsequently, in a fresh bath, the wool portion. A suitable dyeing system comprises LANASOL / MAXILON dyes.

An afterwash with ammonia, soda ash or sodium bicarbonate at pH 8.0–8.5 is required to remove surface or unfixed dyes.

WOOL/COTTON BLENDS

Available for many years.
- Demand is affected by fashion

Advantages
- Very soft handle
- Cost of cotton is less than wool
- Used in woven products (e.g. wool denim)

Limitations
- Dyeing is usually lengthy and often costly.
- Blends of cotton with felt-resist treated wool are particularly difficult to dye.

http://www.merino.com/wool-denim/

13 - **Module 7:** Dyeing of wool blends

EXPLAIN THAT wool/cotton blends have been used commercially for many years, but with only limited market penetration. There are religious restrictions to their use in some communities.

NOTE THAT these blends improve the handle of a cotton-only alternative and are found most commonly in woven wear, such as shirting material and denim.

INDICATE THAT although the cost of cotton is less than that of wool, the lengthy and often costly dyeing procedures required balances the savings so these blends tend to be used in high-value products.

POINT OUT that blends of cotton with felt-resist treated wool (normally required in wool/cotton blends) have proved particularly difficult to dye.

HAND OUT *samples of wool/cotton denim and cotton denim to the participants.*

ASK *participants for comments on handle of the two samples.*

ACKNOWLEDGE *responses.*

WOOL/COTTON BLENDS — PREPARATION FOR DYEING

Preparation may include de-sizing, setting, scouring and/or bleaching.

- Normal alkaline scouring processes for cotton yarn or fabrics must be avoided as they will damage the wool fibre.
- Mildly acid–neutral processes for stain removal are satisfactory.
- Enzyme de-sizing can be used on both cotton and wool.
- Conventional cotton pre-bleaching methods can cause excessive damage to wool — neutral or mildly acid bleaching processes are preferable.

14 - **Module 7:** Dyeing of wool blends

EXPLAIN THAT the preparation of wool/cotton blended products for dyeing depends upon:

- the form of the substrate (yarn or fabric)
- the nature of the product (carded or combed cotton)
- the machinery available.

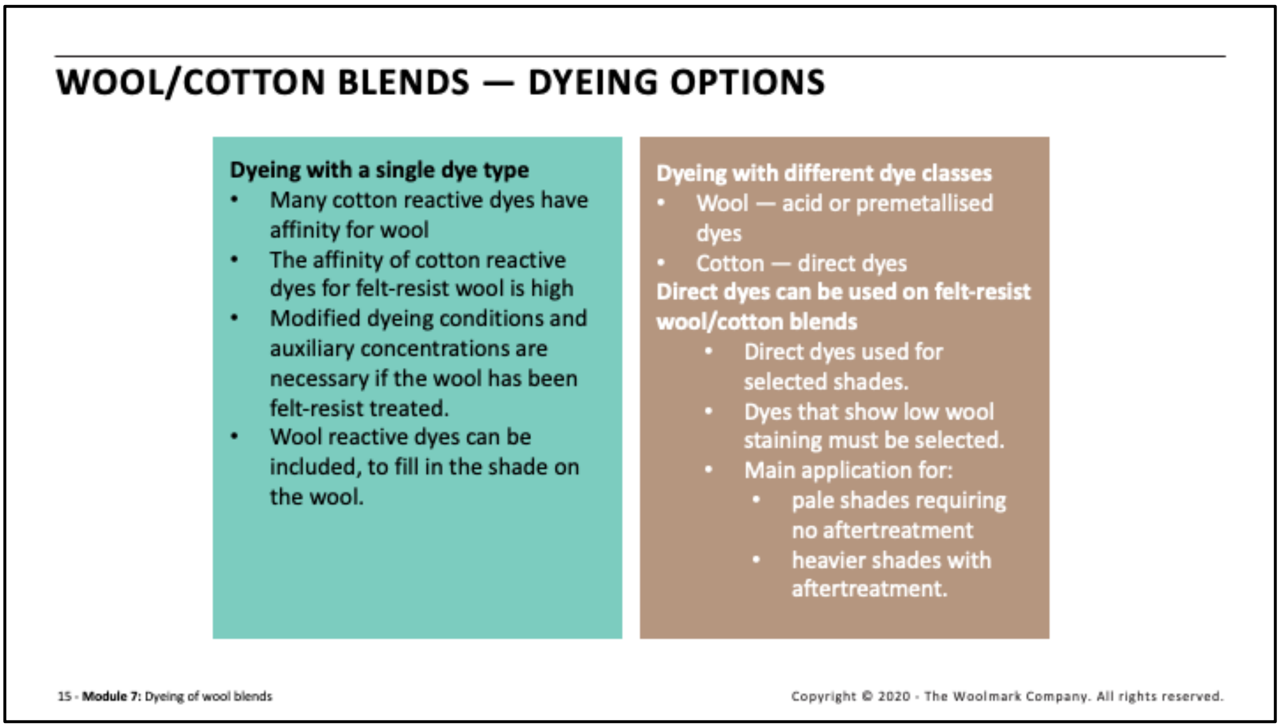
Preparation of the substrate may include de-sizing, setting, scouring and/or bleaching.

INDICATE THAT processors should avoid treatment under alkaline conditions as these conditions will damage the wool fibre. The alkaline sizing and scouring processes used for cotton yarn or fabrics must be avoided to minimise damage to the wool fibre and reduce wool staining in dyeing.

Neutral or mildly-acid-bleaching processes are preferable to alkaline methods to reduce wool staining during subsequent dyeing.

NOTE THAT newer enzymatic de-sizing can remove the starch components of size without damaging the wool fibre.

MENTION THAT conventional cotton pre-bleaching methods can also cause excessive damage to wool and therefore alternative processes must be used.



EXPLAIN THAT wool-cotton blends may be dyed in a number of ways as described below.

Dyeing with the same dye class (e.g. reactive dyes)

- Many cotton reactive dyes have affinity for wool.
- The affinity of cotton reactive dyes for felt-resist wool is much greater than for untreated wool.

Dyeing with different dye classes.

- Wool can be dyed with acid or pre-metallised dyes.
- Cotton can be dyed with direct dyes.

Felt-resist wool/cotton blends

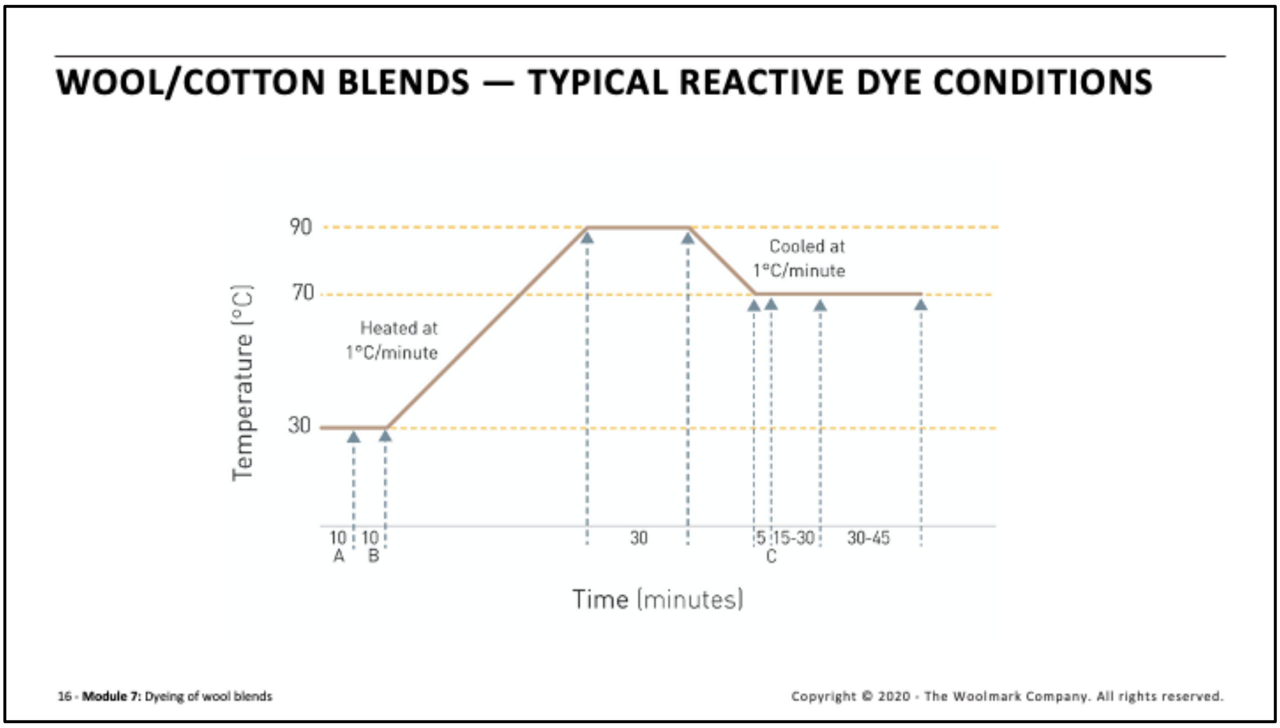
Felt-resist-treated wool has a greater affinity for anionic dyes than untreated wool. The use of an anionic retarder is necessary to control dye uptake by the wool. Typical application levels can be up to 6% on total weight of goods depending on the shade.

NOTE THAT direct dyes have proved useful for selected shades on felt-resist wool/cotton blends.

Their main application is for:

- pale shades requiring no aftertreatment (often dyed on yarn packages)
- shades up to heavier depths (often dyed on piece goods, where the aftertreatment is more easily applied).

INDICATE THAT many ranges of direct dyes are available. Dyes that show low wool staining can be selected for dyeing felt-resist wool/cotton blends.



INDICATE THAT the modified dyeing conditions and auxiliary concentrations necessary when dyeing felt-resist wool/cotton blends is shown on the slide.

Point A

Set bath with:

- Deaerating agent (0.5g/l)
- Sequestering agent (0.5g/l)
- Anti-reduction agent (1.0g/l)
- Anionic retarder (2–5%)
- Dispersant/protective colloid (2.0g/l)
- Common or Glauber's salt (10–50g/l)
- Acetic acid/soda ash to pH 7.0

Point B

Add reactive dyes

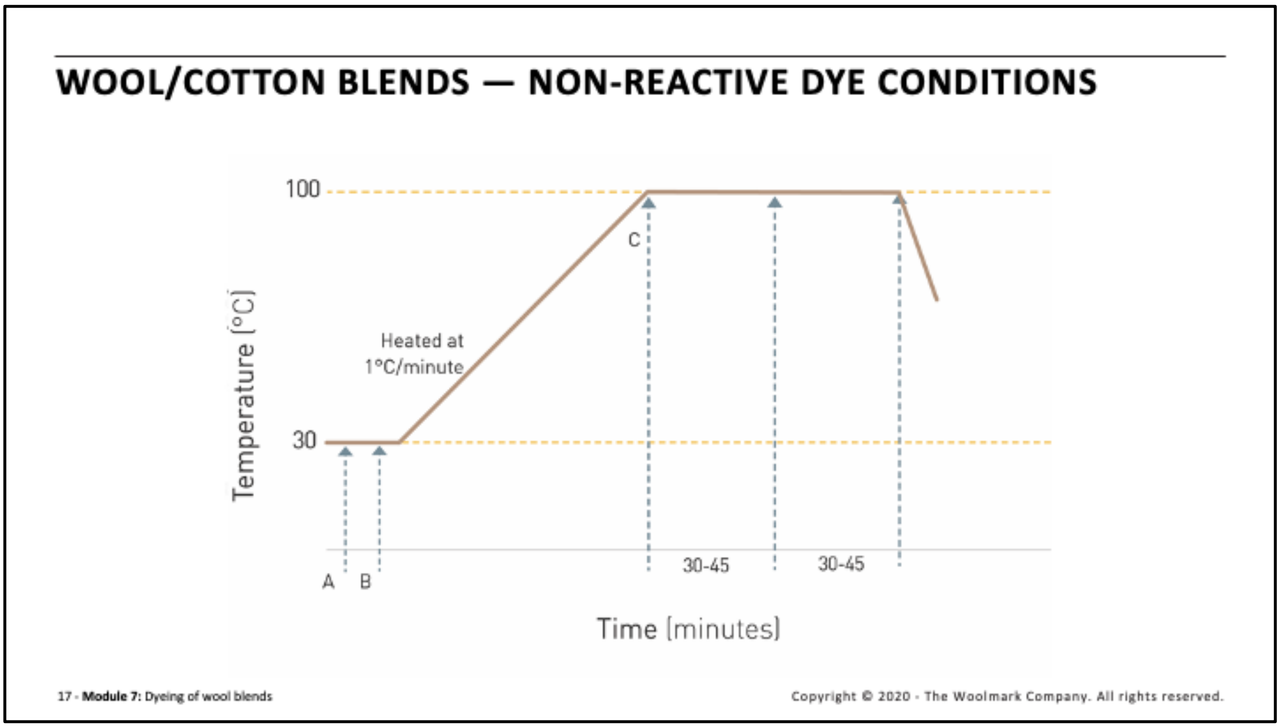
Point C

Fixation

- Soda ash 5–10g/l (dosed or added in portions over 15–30 minutes) to ensure a final pH of 9.8–10.2.

EXPLAIN THAT anionic retarders have a buffering effect and consequently more soda ash is required as retarder levels increase.
Rinse cold to remove excess dye, salt and alkali.

POINT OUT that before washing off hot, neutralise the bath to pH 7.0 at 40-50°C with acetic acid to avoid damaging the wool component during soaping.



INDICATE THAT dyeing with direct dyes (cotton) and acid dyes (wool) is normally confined to piece dyeing or pale shades on yarn.

REFER participants to the following procedure, outlined below and on the slide, which is suitable for dyeing a cotton wool blend with a combination of direct and acid dyes.

Point A

- Dyebath lubricant (1.0 g/l)
- Levelling agent depends on substrate
- Ammonium sulphate (4%)
- Anionic retarder (4–6%)
- Acetic acid to pH 6.5—6.8

Point B

- Dyes (acid and direct)

Point C

- Salt additions

Cationic aftertreatment

This step is essential to achieve adequate wet fastness on all except pale shades.

Set the bath cold with:

- Sodium sulphate (5 g/l)
- Indosol E50 Liquid (0.5–2.0%)
- Ammonia/acetic acid to pH 6.5–7.0

Raise to 60°C and run for 15–20 minutes.
Rinse.

NOTE THAT softeners can be applied in the aftertreatment bath, providing they are non-ionic or cationic.

WOOL/SILK BLENDS

www.tessuti-shop.com/collections/wool-blends

Wool/silk blends (5–50% silk) are mainly used for luxury apparel (woven and knitted products).

Silk is chemically similar to wool and can be dyed with the same dyes.

The quality and type of silk fibres influence the distribution of dyes between silk and wool.

The silk used in blends should be de-gummed before fibre blending to avoid any negative influence of the silk gum.

18 - **Module 7:** Dyeing of wool blends

INDICATE THAT wool/silk blends (5–50% silk) are mainly used for woven and knitted apparel to impart a luxury character.

Silk is proteinaceous so chemically related to wool and can be dyed with the same dyes.

NOTE THAT the quality and type of silk fibres (e.g. mulberry silk, tussah silk, weighted silk) influence the distribution of dyes between silk and wool.

EXPLAIN THAT the silk used in blends should be de-gummed before fibre blending to avoid any negative influence of the silk gum on dyeing performance and fastness.

WOOL/SILK BLENDS — CONDITIONS FOR DYEING

Glauber's salt is the major reagent to control the distribution of dyes.

- Salt retards the dye uptake on wool in favour of silk.

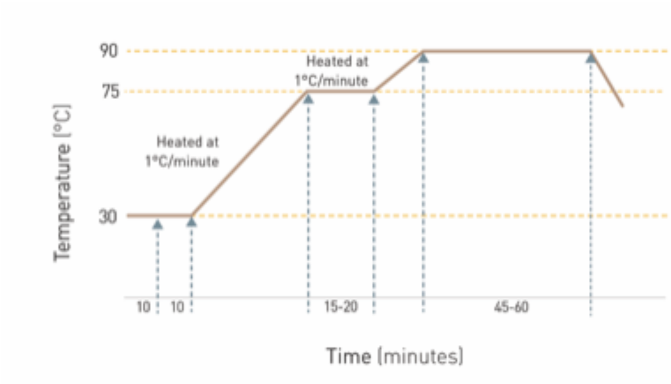
The distribution of dyes depends on the pH used.

- A lower pH favours a deeper dyeing of silk.

Dyeing at a low temperature:

- favours a deeper dyeing on silk
- negatively affects the wet fastness on wool.

The best temperature for dyeing a wool/silk blend is 90°C.



19 - **Module 7:** Dyeing of wool blends

MENTION THAT Glauber's salt is the major reagent used to control the distribution of dyes between wool and silk. Salt retards the dye uptake on wool in favour of silk.

NOTE THAT the distribution of dyes between the two fibres depends on the pH used. A lower pH favours a deeper dyeing of silk.

INDICATE THAT dyeing at a low temperature favours a deeper dyeing on silk, but has a negative influence on the wet fastness on wool. The best temperature is 90°C.

WOOL/MAN-MADE FIBRE BLENDS

Wool can be blended with a number of man-made fibres.

Regenerated cellulosic fibres:
- dyeing similar to wool cotton blends
- provision for differences in dyeing rates.

Chemically modified cellulose:
- acetates
- triacetate.

Regenerated protein fibres (azlons):
- dyed using same dyes as wool
- dyed under similar conditions
- provision for difference in dyeing rates.

20 - **Module 7:** Dyeing of wool blends

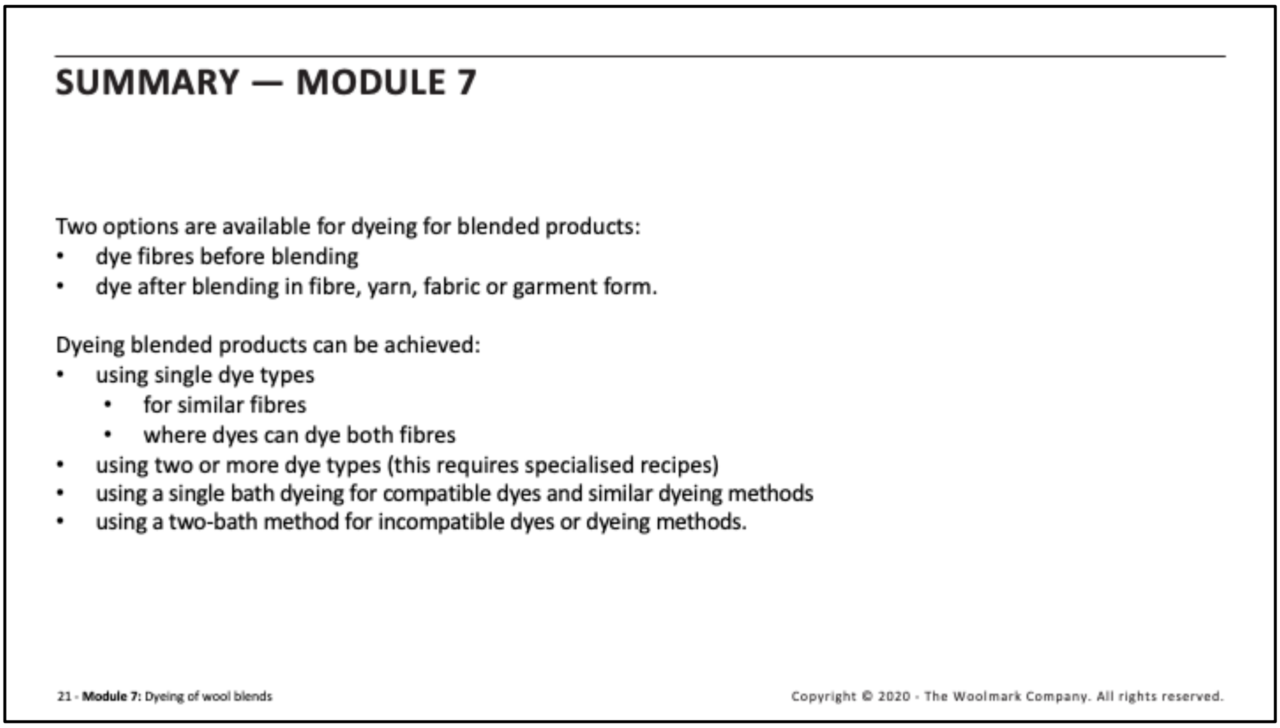
INDICATE THAT as previously discussed, wool can be blended with man-made fibres.

NOTE THAT man-made fibres can be classified into three major classes:
- regenerated cellulose fibres (e.g. rayons and Tencel).
- chemically modified cellulose derivative fibres (e.g. cellulose acetates and triacetate)
- regenerated protein fibres (azlons). This group includes fibres derived from a range of protein sources (e.g. milk, peanuts etc).

Regenerated cellulose fibres:
EXPLAIN THAT there are many rayon manufacturers and, although chemically similar, these fibres can vary in their dyeing characteristics.
The blends with cellulosic fibres are dyed using methods similar to wool–cotton blends, although adjustments have to be made to account for the differences in the rate of dyeing and total dye uptake of the regenerated fibre and cotton.

Chemically modified cellulose derivative fibres:
NOTE THAT cellulose acetates and triacetate can be dyed with disperse dyes and methods based on the co-application of acid and disperse dyes can be used on wool blends.

Regenerated protein fibres:
POINT OUT that like silk, the regenerated protein fibres can be dyed with most wool dyes. Also like silk–wool blends, allowance for the differences in the strike rates and total exhaustion of the wool and the azlon must be made. These differences depend on the type of azlon used and its method of production (wet spinning etc).



SUMMARISE THAT dyeing wool blends is not easy. It needs detailed recipe development in the mill and laboratory to achieve solid shades, while ensuring the quality of the wool is preserved and damage is minimised.

REITERATE THAT two options are available for dyeing for blended products:

- dye fibres before blending
- dye after blending in fibre, yarn, fabric or garment form.

REMIND participants that dyeing blended products can be achieved by:

- using single dye types
  - for similar fibres
  - where dyes can dye both fibres
- using two or more dye types (this requires specialised recipes)
- using a single bath dyeing for compatible dyes and similar dyeing methods
- using a two-bath method for incompatible dyes or dyeing methods.

SUMMARY (CONTINUED)

Wool/synthetic blends

- The differences between the chemistry of the fibres impact dyeing methods.
- Wool/nylon blends dyed with one dye type.
- Wool/polyester require specialised auxiliaries:
    - carriers at >105°C
    - wool protective agents.

Wool/natural fibre blends

- Wool/silk blends can be dyed with one dye type.
- Wool/cotton blends can be dyed:
    - with reactive dyes in a single bath
    - with a mixture of wool and direct dyes.

Wool/man-made fibre blends

- Regenerated cellulose derived.
- Regenerated protein.

22 - **Module 7:** Dyeing of wool blends

REMIND participants that in general, it is easier to dye wool/polyamide and wool/acrylic blends as they are dyed at acidic – neutral pH and 98°C. Wool/silk blends are also dyed at acidic pH, but are dyed at low temperatures, so fastness in the wool component is always a concern.

REVIEW the fact that wool/polyester blends are more difficult to dye:

- Damage to the fibre must be balanced against dye fastness and the final handle of the product.
- Thermal migration of the disperse dye is also an issue.

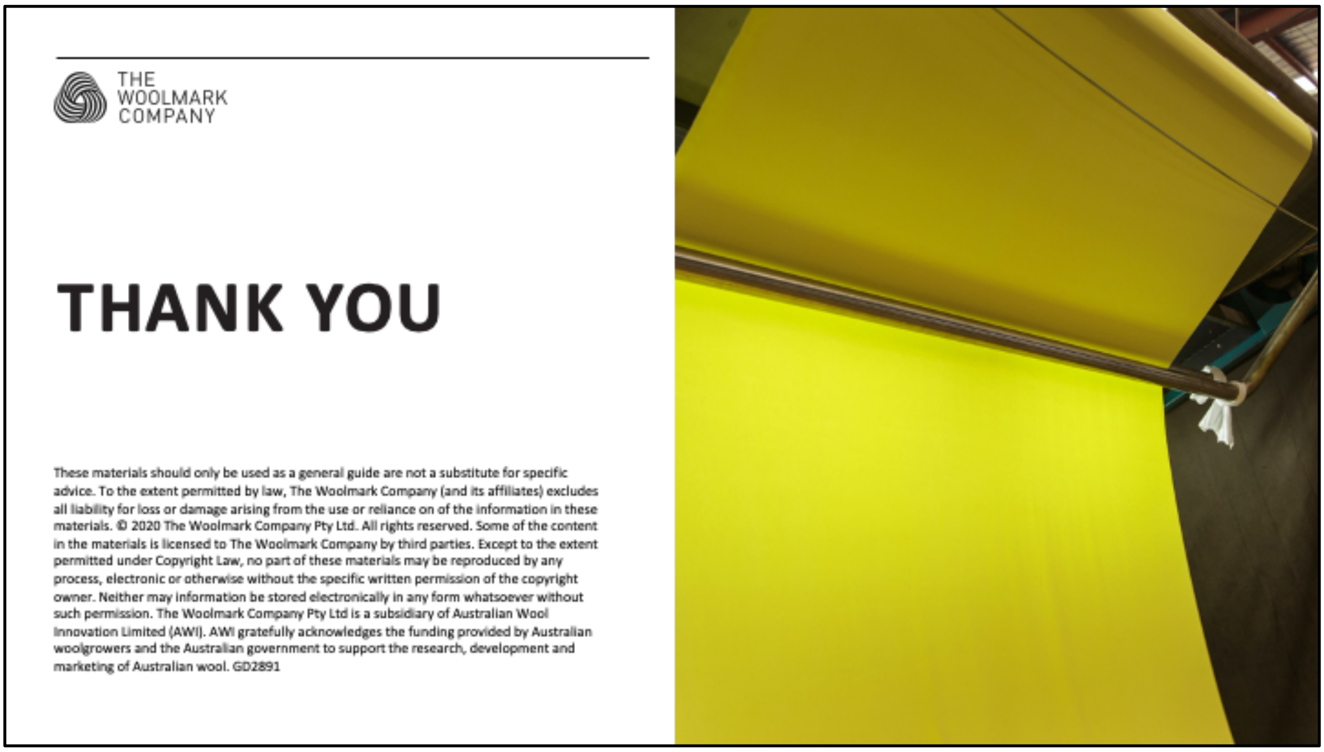
REVIEW the fact that wool/cellulosic blends are the most difficult to dye to solid shades. The handle of the product will be affected by the alkaline conditions during the pre-treatment, dyeing and soaping processes required for the cellulosic component.

REITERATE THAT wool/man-made fibre blends can be dyed using recipes suitable for cellulose blends or wool modified for the different dyeing characteristics of the regenerated fibres.

Chemically modified regenerated fibres can behave more like synthetic fibres.

***ASK** participants if they have any questions about the content covered in this module.*

***ALLOW** time for questions and discussion before proceeding to the final slide and closing the lecture.*



INFORM participants of the time and location for the next lecture — *Module 8 The dyehouse laboratory* — and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

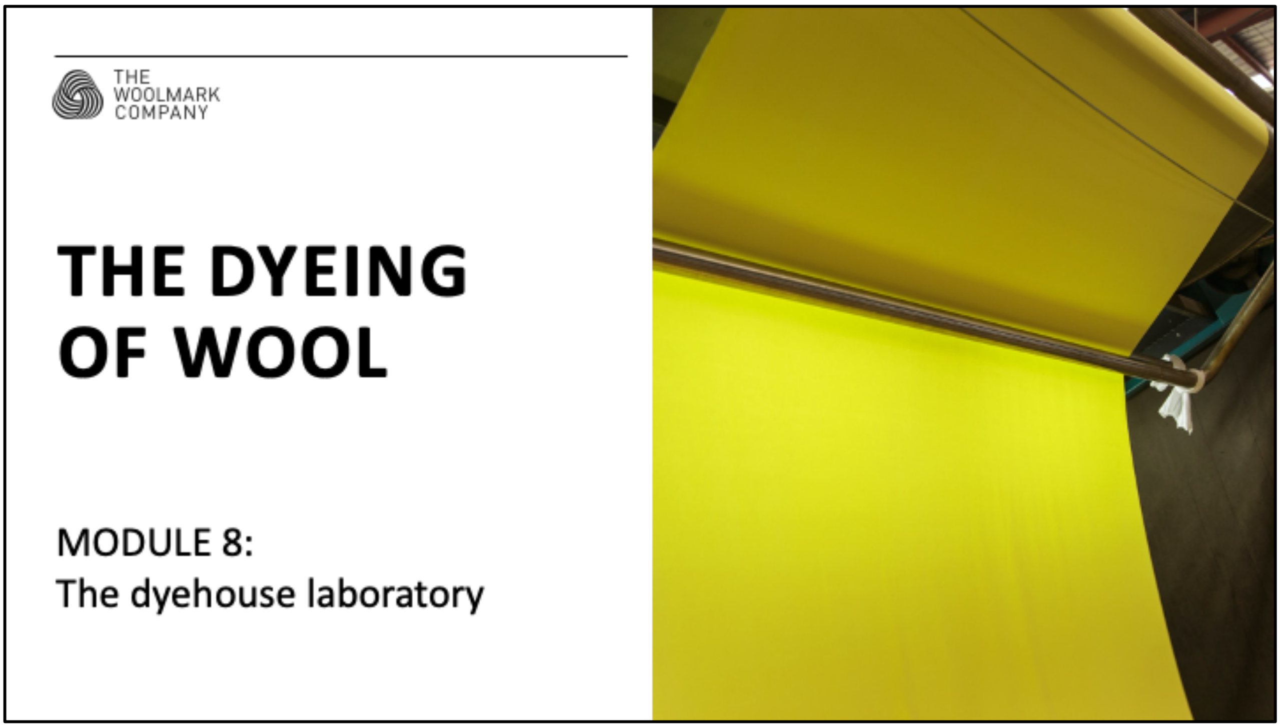
MODULE 8

THE DYEHOUSE LABORATORY

RESOURCES — MODULE 8: THE DYEHOUSE LABORATORY

Contained in *The dyeing of wool* Demonstration kit you will find the following resources for use as you deliver **Module 8: The dyehouse laboratory**

- grey scales — colour change
- grey scales — staining
- light fastness samples
- wash fastness samples



WELCOME participants to Module 8 of the Woolmark Wool Science, Technology and Design Education Program — *The dyeing of wool — The dyehouse laboratory.*

MENTION THAT the dyehouse laboratory is an essential component of an efficient dyehouse.

The laboratory is the focus of all the control and development activities of the dyehouse.

EXPLAIN THAT adequate dyehouse laboratory facilities are vital to manufacturing operations. They provide key support to development, production and sales functions and include:

- analysis and control of water, new dye lots
- analysis and control of new substrate batches
- shade matching and recipe production
- evaluation of new dyes and auxiliaries
- development of new products and processes
- trouble shooting
- technical service for sales department and customers
- fastness assessment
- quality control.

INFORM participants that by the end of this module they will be able to:

- describe the use and action of key test equipment used in a dyehouse laboratory.

RESOURCES REQUIRED FOR THIS MODULE

- *grey scales – colour change*
- *grey scales – staining*
- *light fastness samples*
- *wash fastness samples*

LABORATORY LAYOUT

- Air conditioning advisable, particularly in colour measurement and sample preparation area.
- Separate the dye, chemical and sample substrate storage from the weighing areas to prevent contamination.
- A light cabinet is essential for visual assessments.

Sample dyeing machine

2 - **Module 8:** The dyehouse laboratory

EXPLAIN THAT the dyehouse laboratory provides the quality assurance test data and development facilities for the dyehouse. The testing must be conducted under optimised conditions to ensure the reproducibility and reliability of data.

INDICATE THAT ideally, the whole of the laboratory should be air conditioned, particularly the colour measurement and sample preparation area, because the moisture content of samples affects their weight and can affect colour measurements.

NOTE THAT the dye, chemical and sample substrate storage and weighing areas should be separated to prevent contamination from powdered dye 'fly'.

POINT OUT that the provision of a north-facing (south-facing in the southern hemisphere) window is not essential if an accredited light cabinet is used for visual inspections and assessments, but is recommended.

MACHINERY AND EQUIPMENT

Balances

Solution preparation and dispensing

Small scale dyeing machines
- Reciprocating action
- Rotating
- Circulating liquor

pH meter

Viewing cabinet

Dyes, chemical and fabric storage

Sample dyeing machine

3 - **Module 8:** The dyehouse laboratory

EXPLAIN THAT the types of equipment required in a dyehouse laboratory include:
- balances for weighing dyes, chemicals and substrates
- solution preparation and dispensing equipment for measuring dye solutions
- small-scale dyeing machines for the development and testing of dye types and recipes
    - reciprocating action — vertical
    - rotating — closed stainless steel pots with dye liquor and textiles are circulated in a heating fluid or heated with infrared radiation
    - circulating liquor — where the textile is stationary and the dye liquor is pumped through it
- pH meter (The pH of wool substrates can have a marked effect on dyeing performance, particularly when applying fast dyes, such as 1:2 metal complex, milling and reactive dyes.)
- viewing cabinet assessing colour and fastness test samples
- dyes, chemical and substrate storage.

NOTE: The dyeing machines in the laboratory should closely simulate the action of commercial dyeing machines.

There are many suppliers available for such equipment.

COLOUR MEASUREMENT

Sample preparation is important.

- **Fibre dyeing:**
  - Felt pad
  - Sample spin and knit (for sliver)
  - Glass-fronted fibre holder
- **Dyed yarn:**
  - knitting
  - winding on a former.
- **Dyed fabric:**
  - unfinished
  - finished.

Spectrophotometer

4 - **Module 8:** The dyehouse laboratory

INDICATE THAT colour measurement is a critical tool in any modern dyehouse laboratory. It must be used in the correct way if meaningful results are to be achieved.

EXPLAIN THAT there are now many suppliers of colour measurement equipment and software. Some instruments include dyehouse management and machine control functions. A viable system will include at least recipe prediction and colour quality software. Additional software for functions, such as whiteness and colour fastness ratings is available. These are useful but not essential.

Sample preparation and presentation

NOTE THAT for fibre dyeing the following options are main ways samples are prepared:

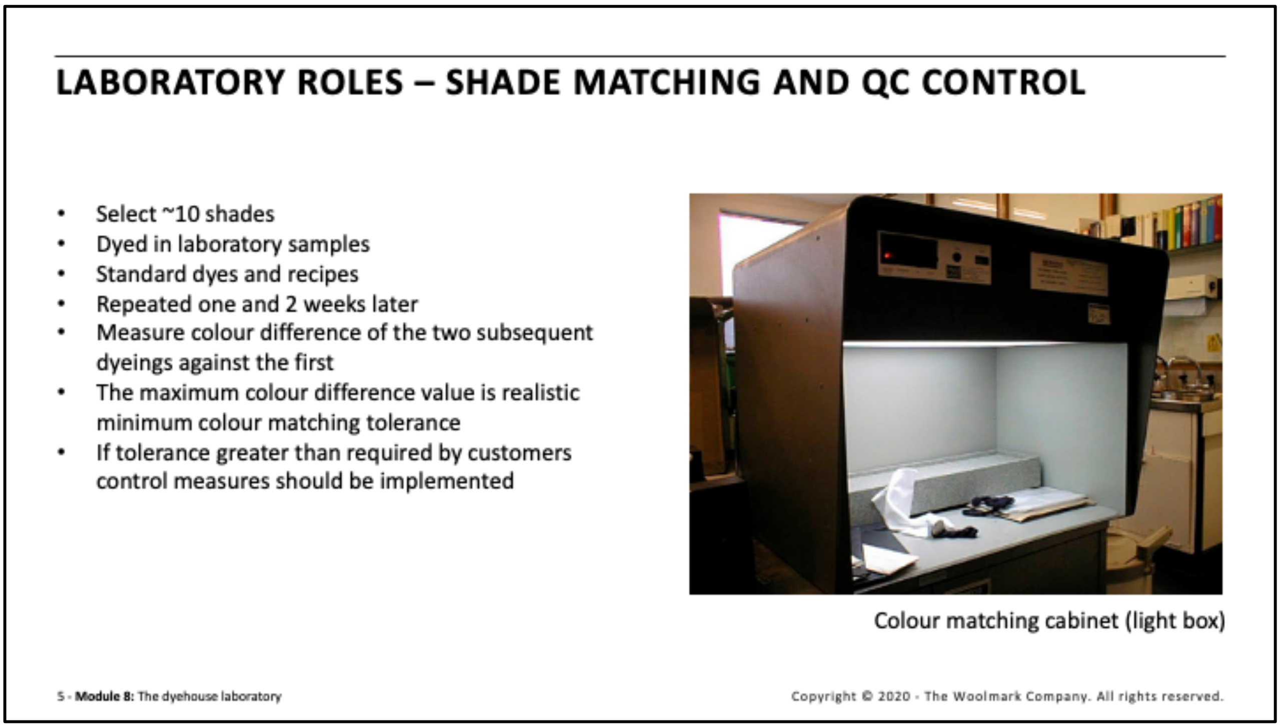
- felt pad
- sample spin and knit (for sliver)
- glass-fronted fibre holder.

MENTION THAT dyed yarn samples should be prepared for colour measurement or visual assessment by either knitting or winding on a former.

POINT OUT that dyed fabric samples for colour assessment will normally be unfinished. However the shade can change during finishing so a sample of the finished material should be subsequently measured.

HAND OUT s*amples used to measure colour to participants.*

ASK *participants if they have any questions or comments about the samples.*



INDICATE THAT accurate shade matching and control involves evaluating the precision of dyeing exhibited by the dyer.

EXPLAIN THAT to measure the precision of colour measurement and recipe reproducibility:

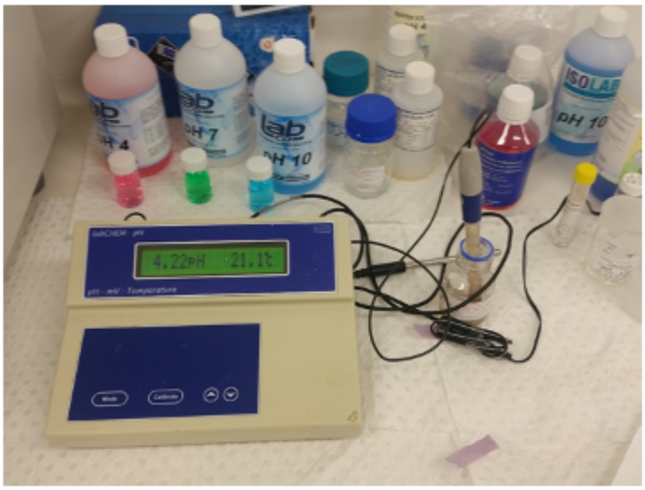
- around 10 shades should be selected
- samples should be dyed as laboratory samples, using standard dyes and recipes
- the dyeings are then repeated one week and a number of weeks later
- the colour difference of the two subsequent dyeings is measured against the first
- the maximum colour difference value for all shades will be the realistic minimum colour matching tolerance.

NOTE THAT if this tolerance is greater than required by customers, control measures should be implemented.

POINT OUT that the system described above can obviously not be duplicated in production and must be done in the laboratory. During production, the colour difference values between a previously-dyed lot and repeat batches to the same recipe should be measured and recorded. Quality assurance programs should be implemented to minimise any differences.

TESTS CONDUCTED

- pH of wool
- Strike and migration test
- Skittery dyeing



6 - **Module 8:** The dyehouse laboratory

INDICATE THAT specific tests are conducted by the laboratory. Among the more important are:

The pH of wool substrates
The test is based on IWTO-2-96 and is conducted as follows:
- Weigh 2g of wool and place in a conical flask with 100ml deionised water.
- Shake for 1 hr and measure the pH with a calibrated pH meter.

An assessment of rate of strike and migration
EXPLAIN THAT there are several methods for testing the rate of strike and migration of dye into the fibre and the one below is given as an example.
- Prepare a dyebath to dye 10g of the substrate, but start the dyeing with just 4g of substrate at 40°C.
- Increase the temperature to the boil at 1°C per minute and after every 10 minutes add a further 1g of the substrate to the dyebath.
- Continue dyeing for 60 minutes.
- The differences in depth and hue (if a multiple dye recipe is used) between the specimens illustrate the strike and migration behaviour.

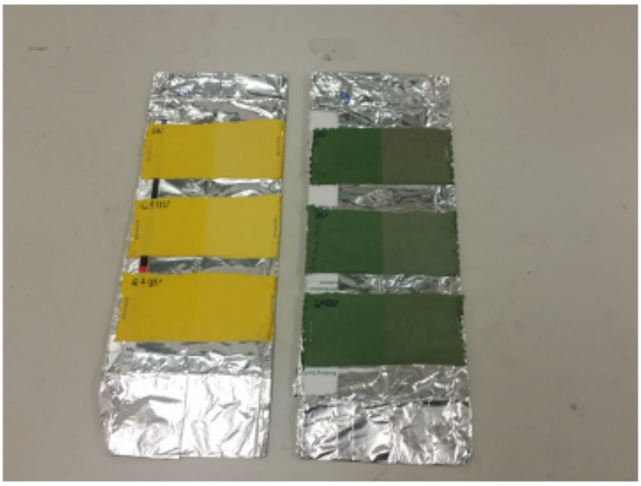
The potential of wool materials to dye in a skittery manner
NOTE THAT this is assessed by dyeing a sample with:
- C.I. Reactive Yellow 39 (1.0%)
- C. I. Acid Blue 185 (1.0%)

The dyeing should be carried out at pH 5.0.

Fastness tests are covered in the next slide.

TESTS CONDUCTED (CONTINUED)

- Fastness to light
- Fastness to water
- Fastness to hand washing
- Fastness to machine washing
- Fastness to dry cleaning
- Fastness to perspiration
- Fastness to chlorine
- Fastness to rubbing (crocking)



7 - **Module 8:** The dyehouse laboratory

The fastness of dyes to a range of conditions

INDICATE THAT dye fastness is required to meet:

- the requirements of subsequent processing and product use
- the customer's requirements
- any regulations pertinent to the ultimate product

MENTION THAT the types of fastness testing carried out in a dyehouse laboratory depends on the nature of the textile being dyed.

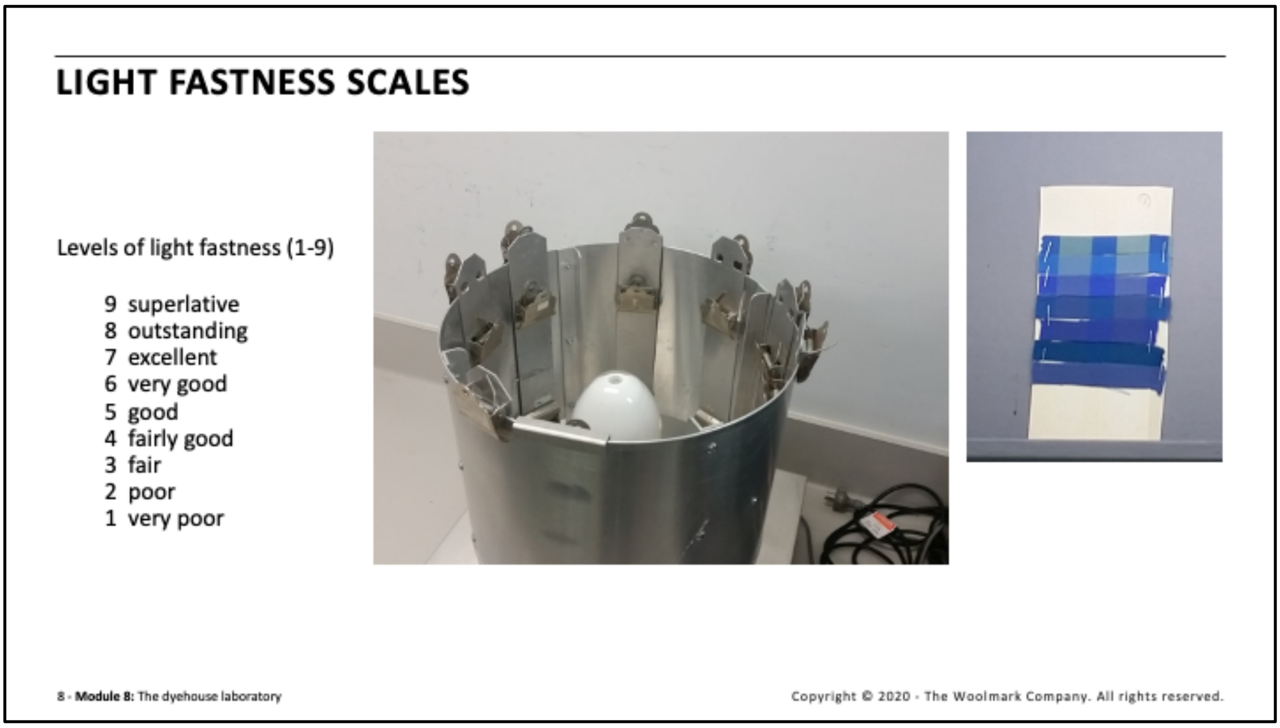
REFER participants to the list on the slide which represents the basic tests from which routine quality control testing should be selected.

POINT OUT that additional tests may be needed for specific end uses, blends and other fibre types (e.g. sublimation fastness)

NOTE THAT testing should be carried out after the application of any subsequent processes to which the material will be subjected during production.

HAND OUT *wash fastness test samples to participants.*

ASK *participants if they have any questions or comments about the samples.*



INDICATE THAT light fastness is determined by exposing to an agreed light source, the dyed product simultaneously with specialised fabrics with graded light fastness.

NOTE THAT modern test methods require a Xenon arc lamp although alternative lamps have been used (and still are used for specific applications).

EXPLAIN THAT the relevant test methods (e.g. ISO 105-B02:2013) are well established and detail :

- the light source and its specifications
- the procedure for exposing and examining the test samples
- the determination of the end point of exposure
- the criteria for pass or fail of required specifications.

MENTION THAT simpler set-ups can also be used like that shown on the slide using an MTFB lamp, but lack the precision of the modern Xenon test instruments.
The standard fabrics used to assess level of exposure are also shown in the slide.

HAND OUT *light fastness test samples to participants.*

ASK *participants if they have any questions or comments about the samples.*

RATING FASTNESS USING GREY SCALES

Colour change and staining are rated against ISO grey scales on a 1–5 scale

Colour Change
- 5 negligible or no change
- 4 slightly changed
- 3 noticeably changed
- 2 considerably changed
- 1 much changed

Staining
- 5 excellent
- 4 good
- 3 fair
- 2 poor
- 1 very poor

Colour change grey scales

Staining grey scales

9 - **Module 8:** The dyehouse laboratory

Evaluating the outcome of other fastness tests

INDICATE THAT tests other than fastness to light involve testing the dyed product according to the relevant method (e.g. wash fastness) and observing:

- the change in colour
- the amount of staining on a range of different fibre types (available on a specially prepared sample).

NOTE THAT the relevant methods (ISO 105-C06:2010) detail:

- the procedure for testing the samples
- the procedure for rating the colour change and staining using the grey scales
- the criteria for pass or fail for required specifications.

HAND OUT *the grey scales to participants.*

ASK *participants if thy have any questions or comments about the grey scales.*

SUMMARY — MODULE 8

This module covers the issues associated with the dyehouse laboratory:

- The laboratory is the centre of quality assurance programs
- The equipment required is reviewed
- Test methods used:
    - colour measurement
    - fastness
    - textile properties.
- A range of standards can be applied.

10 - **Module 8:** The dyehouse laboratory

SUMMARISE this module by reminding participants that the laboratory is the centre of quality assurance programs for the dyehouse.

REITERATE THAT the key equipment used in the laboratory includes:

- colour measurement cabinet (light box)
- sample dyeing machinery
- spectrophotometer
- light fastness standards
- grey scales.

REMIND participants that the test methods used are:

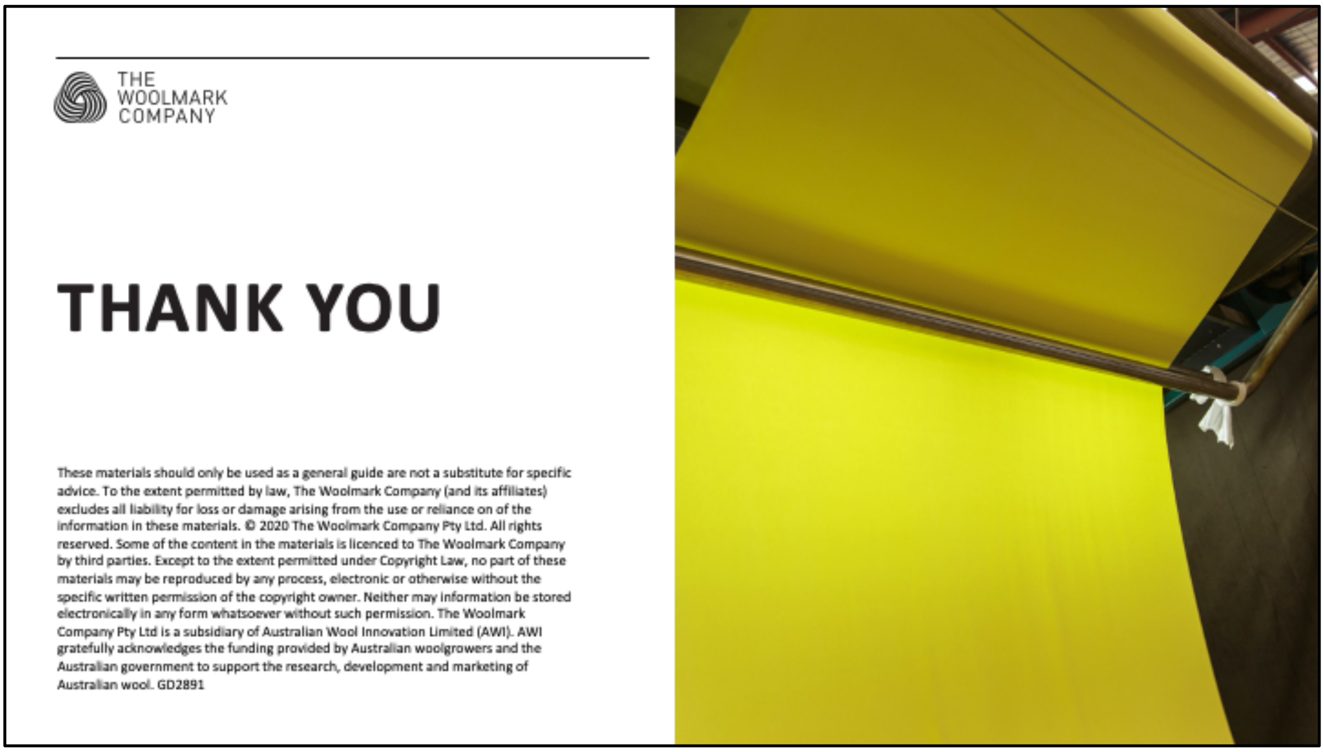
- colour measurement
- fastness
- textile properties.

Full detailed test methods are available from the relevant authority (e.g. ISO).

REVIEW the fact that a range of standards can be applied depending on the nature of the product and the requirements of the customer.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*



INFORM participants of the time and location for the next lecture — *Module 9 The environmental impacts associated with dyeing wool* — and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

THE WOOLMARK COMPANY

MODULE 9

ENVIRONMENTAL IMPACTS ASSOCIATED WITH DYEING WOOL

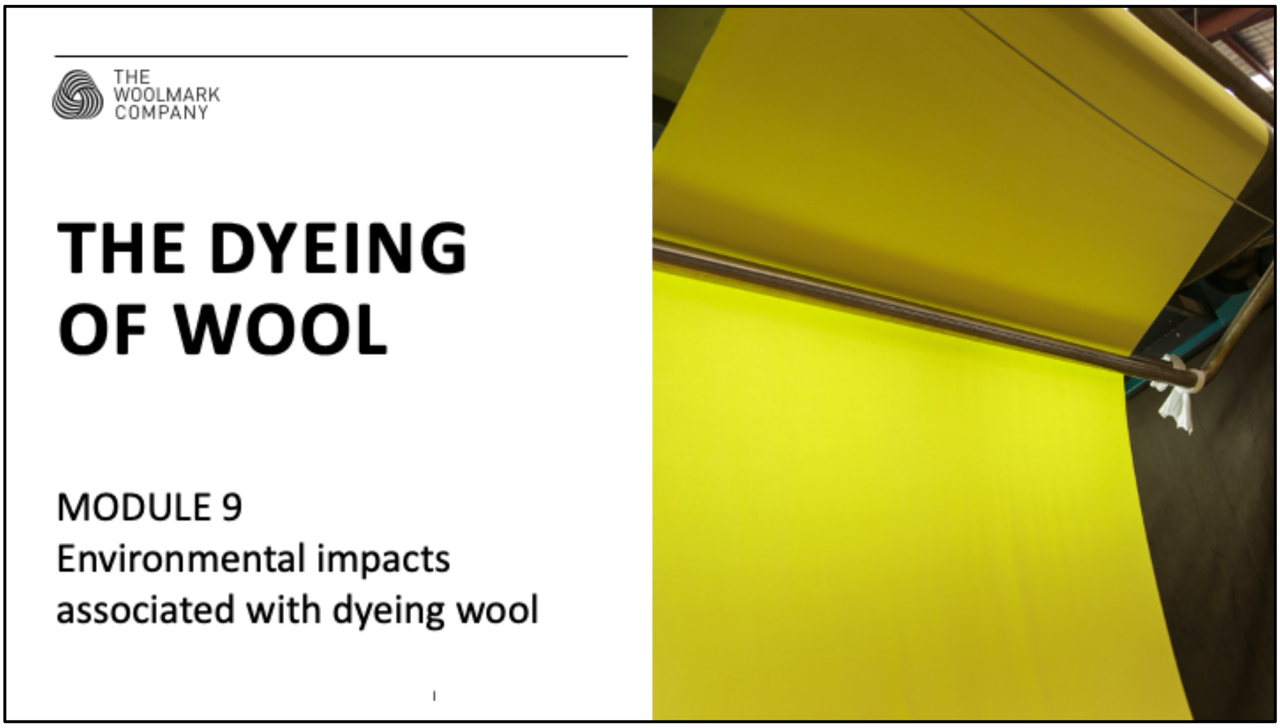
RESOURCES — MODULE 9: ENVIRONMENTAL IMPACTS ASSOCIATED WITH DYEING WOOL

Contained in *The dyeing of wool* Demonstration kit you will find the following resources for use as you deliver **Module 9: Environmental impacts associated with dyeing wool**:

– carbon black

Additional resource to be sourced by the facilitator include:

– solution of a vegetable dye



WELCOME participants to Module 9 of the Woolmark Wool Science, Technology and Design Education Program — *The dyeing of wool — Environmental impacts associated with dyeing.*

POINT OUT that consumers increasingly regard the naturalness and the 'clean, green renewable' image of wool as important in their choice of textiles.

In 2007 an AWI survey showed that 30% of consumers preferred natural or organic apparel.

NOTE THAT an estimated 50% of the carbon footprint of textile products is attributable to dyeing and finishing. Of the remainder.

- 15% is from fibre production,
- 15% is from spinning
- 20% is from weaving or knitting.

It is also estimated that 80% of the environmental impact of apparel textiles occurs during consumer use and only 20% during manufacture

EXPLAIN THAT this module covers some of the environmental issues associated with the wool dyeing process, including the dyeing of blends, which includes its own challenges.

NOTE THAT the specific issues for wool that will be covered in this module include:

- the use of water and energy (an issue for all textiles)
- the use of chrome mordant dyes in wool dyeing
- the impact of statutory regulations on the release of chromium in mill effluent
- the problems associated with potassium dichromate
- the issues of 'superblacks'
- effluent from the dyeing of felt-resist treated top.

INFORM participants that by the end of this module they will be able to:

- nominate the environmental issues associated with dyeing of wool containing products
- describe potential solutions for these problems.

RESOURCES REQUIRED FOR THIS MODULE

- *carbon black*
- *solution of a vegetable dye*

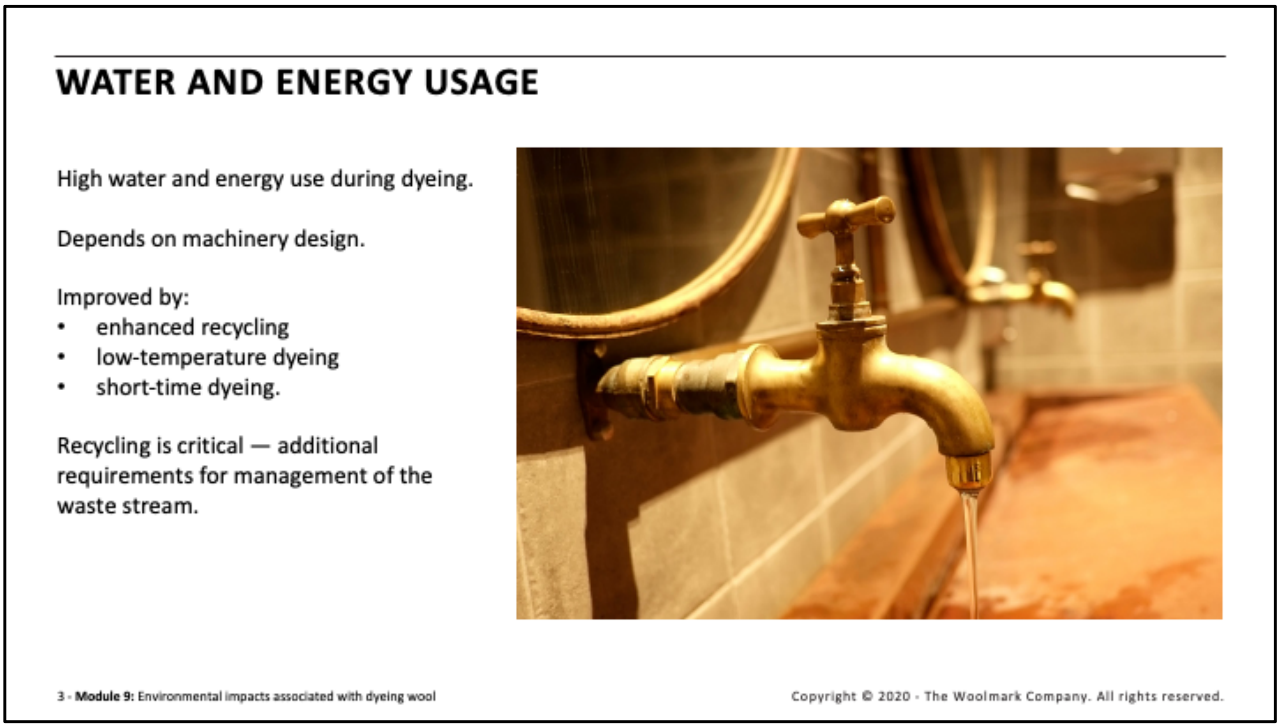
INDICATE THAT wool prides itself on its image of natural, biodegradable, renewable. It is important this image is not degraded by environmentally-unfriendly processing operations.

EXPLAIN THAT many countries are introducing environmental regulations for processing textiles. Some years ago the European Union (EU) introduced legislation to limit the import of goods that contained specific materials — the EU Directive 2002/61/EC . The new EU chemicals policy (REACH) came into force on 1 June 2007 and will be fully implemented between 2010 and 2018.

MENTION THAT wool processors within the EU will be restricted to using chemicals registered under REACH. This could mean some chemicals currently used for processing wool could cease to be available.

China also introduced regulations on effluent control effective from January 2015.

NOTE THAT ensuring wool meets all the regulations and keeps its 'clean green image' will require a process of continual improvement for processors.



EXPLAIN THAT water and energy use is becoming a key part of the cost and environmental challenges associated with the dyeing process.

The use of both resources depends on machinery design and associated operating efficiencies.

INDICATE THAT water and energy usage can be improved by:

- enhanced recycling
- low-temperature dyeing
- short-time dyeing.

NOTE THAT recycling is a critical tool managing water use and there are additional requirements for managing the waste stream from dyeing.

DYEING EFFLUENTS

Wool can be dyed with a range of dye types.

Wool is often blended with other textile fibres, both natural and synthetic.

All effluents can have colour removal issues.

4 - **Module 9:** Environmental impacts associated with dyeing wool

EXPLAIN THAT wool can be dyed with a range of dye types. The effluents from the dyeing process contain different types and levels of chemicals, depending on the type of dye used.

NOTE THAT wool is often blended with other textile fibres, both natural and synthetic. The effluents from dyeing wool blends contain different types and levels of chemicals depending on the type of fibres in the blend and the processes used to treat these blends.

MENTION THAT all effluents can have colour removal issues due to inadequate dye exhaustion. Dyes are associated with 'colour pollution' to many people, as opposed to 'toxic pollution'.

POINT OUT that if colour is observable in an effluent, it is unacceptable, whether it represents a significant pollution hazard or not.

DEMONSTRATION: DYEING EFFLUENTS

Resources required:

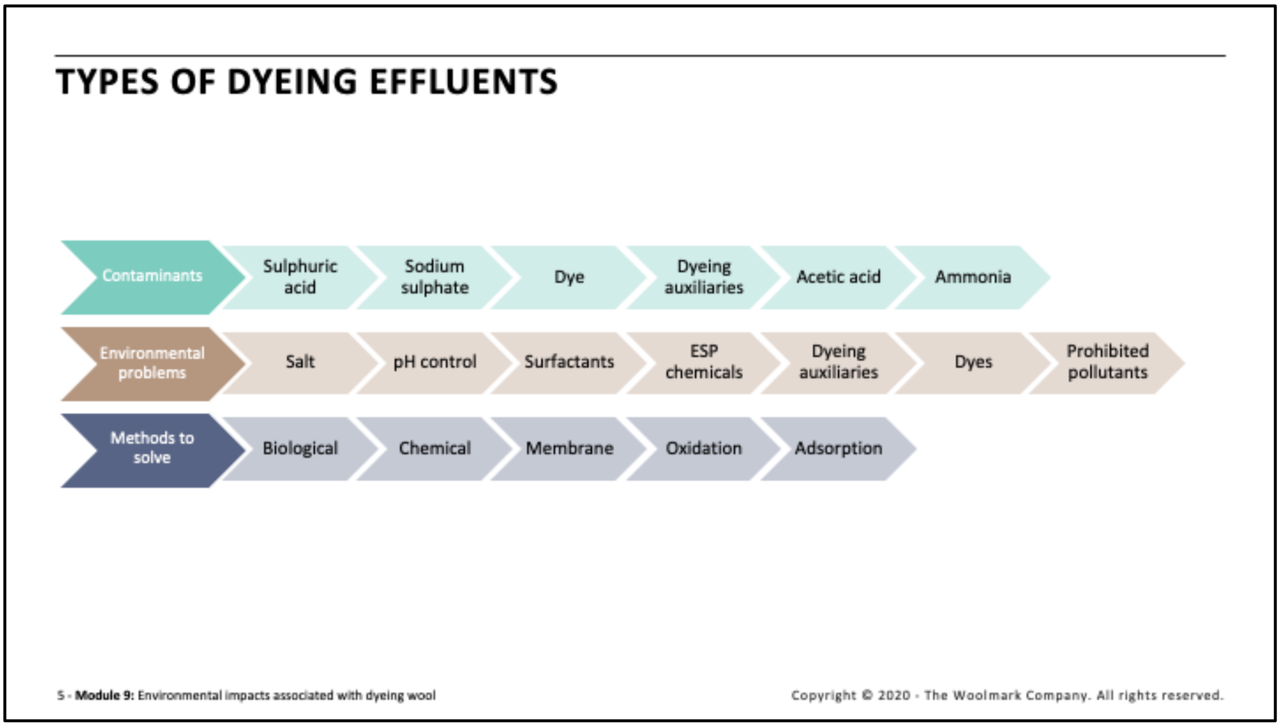
- *carbon black*
- *solution of a vegetable dye*

ADD *carbon black to dye solution and allow to settle.*

ENSURE *all participants can observe the change in colour of the solution.*

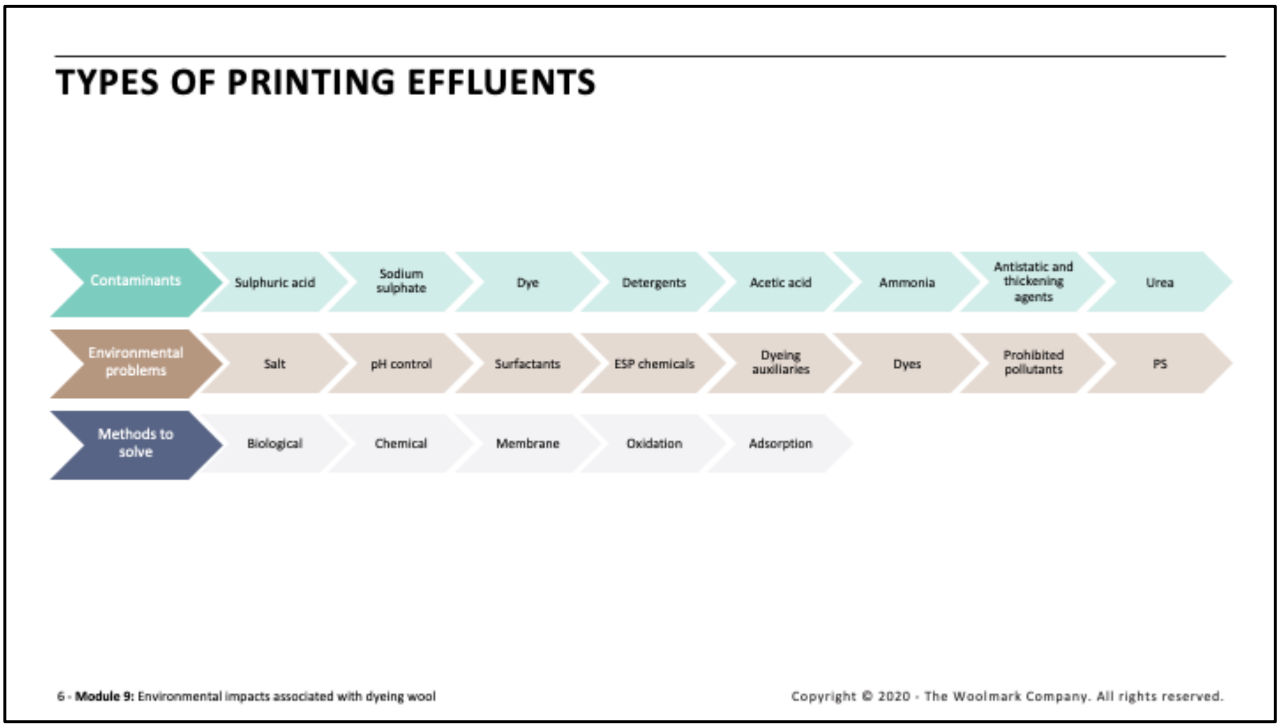
ASK *participants to explain why the colour changed.*

SUGGESTED ANSWER:
Carbon black adsorbed the dye.



NOTE THAT the types of contaminants in effluents from dyeing are listed in the slide above.

EXPLAIN THAT also listed are the potential environmental problems associated with these contaminants and the methods for reducing or eliminating the contaminants in the dyehouse effluent.



INDICATE THAT printing pastes contain many of the same materials as dye liquors, with additional materials for controlling the viscosity of the paste.

NOTE THAT similar methods are used to clean the effluent from printing.

POINT OUT that the products, environmental problems and potential methods to solve these problems are listed on the slide.

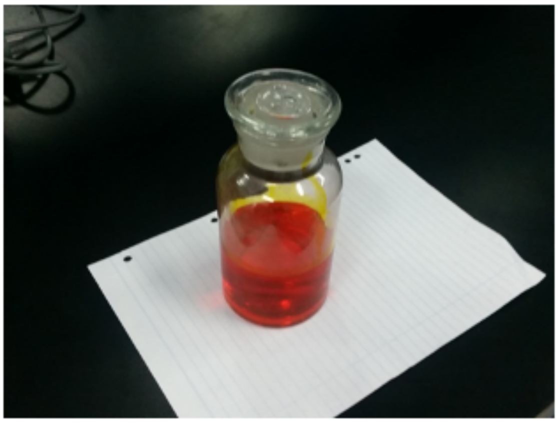
HEAVY METALS USED IN WOOL DYEING

Chrome mordant dyes:
- inexpensive
- high exhaustion rates
- good colour depth
- easy to level
- excellent wet fastness

BUT…

Chrome mordant dyes require the use of potassium dichromate:
- a suspected carcinogen
- a substance of very high concern (EU)

Chromium salts can be released in dyeing effluent.



Chrome dyes make up around 25% of all wool dyes used (mostly black and navy).

7 - **Module 9:** Environmental impacts associated with dyeing wool

EXPLAIN THAT some dyeing processes involve the addition of metal salts, usually as mordants. In such instances care must be taken to avoid release of harmful heavy metal compounds in the dye effluent.

INDICATE THAT chrome dyes are widely used on wool because they:
- are relatively inexpensive
- offer good colour depth
- are easy to level
- have excellent wet fastness.

These dyes make up 25% of all wool dyes used in China (mostly black and navy).

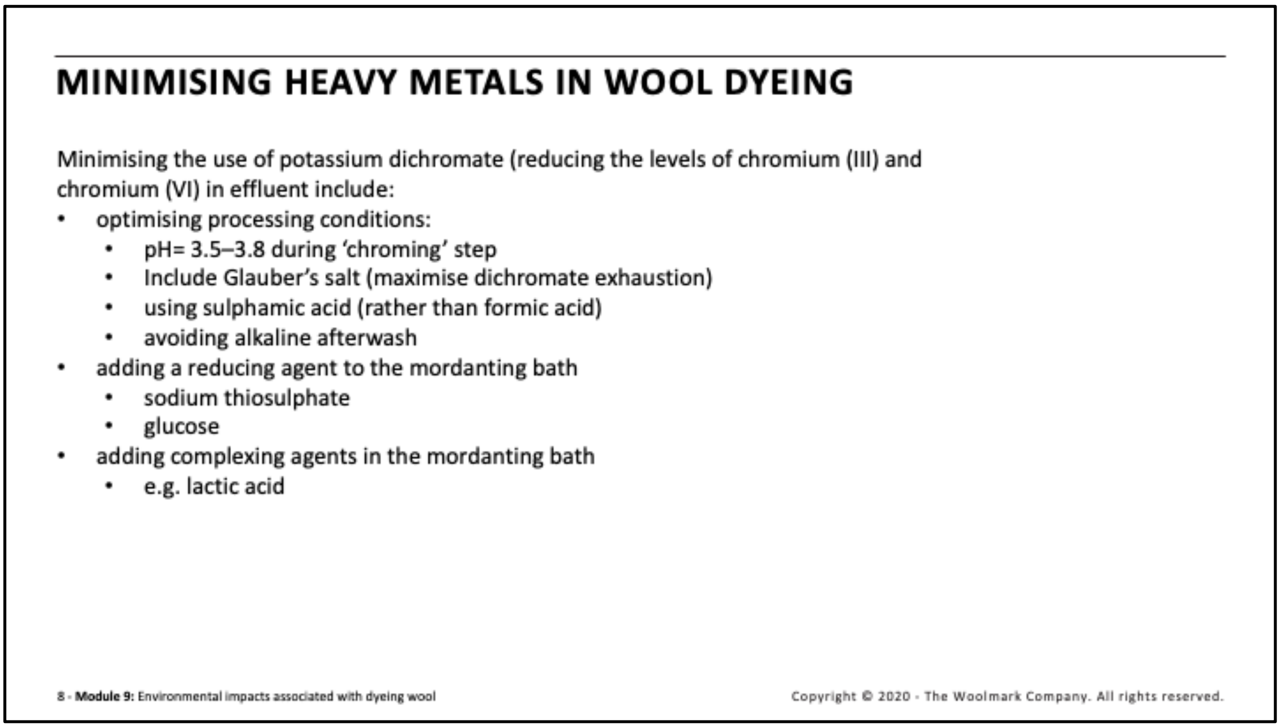
NOTE THAT chrome mordant dyes require the use of potassium dichromate, which is a chromium (VI) material. This compound is a suspected carcinogen and a substance of high concern in the EU in particular.

EXPLAIN THAT when the potassium dichromate is added to the dyebath and enters the wool it is converted to chromium (III). Under the acid conditions used during dyeing with chrome mordant dyes, chromium (III) salts have no substantivity for the fibre, so are not used directly for mordanting.

MENTION THAT the oxidising effect of the chromium (VI) salt, which reduces it to chromium (III), is also important for developing the colour and fastness of the dye. Chromium (III) is of less environmental concern than chromium (VI), however the handling of potassium dichromate remains an issue.

EXPLAIN THAT residual chromium (VI) in dyeing effluent is a significant environmental issue. These salts can be discharged from the dyeing and rinsing effluents. There are strict limits on the discharge of chromium(III) and even stricter limits on the discharge of chromium (VI).

NOTE THAT in China the limits are:
- chromium (VI) – 0.5–1.0ppm
- chromium (III) – 2.0–5.0ppm
- total chromium – 2.0–5.0ppm.



EXPLAIN THAT there are three alternative approaches to minimising, or avoiding, the use of potassium dichromate when dyeing wool . Traditional recipes give effluent that typically contains 200-250ppm total chromium.

Optimise process conditions
By optimising dyeing conditions, the use of potassium dichromate can be minimised. This can be achieved by:

- setting pH at 3.5–3.8 at 80–90°C during 'chroming' step
- including Glauber's salt (to exhaust chromium salt)
- using sulphamic, rather than formic acid
- avoiding an alkaline afterwash

Adding a reducing agent to the mordanting bath
This facilitates exhaustion of the chromium into the wool and converts any residual chromium (VI) to chromium (III). Examples of suitable reducing agents for wool dyeing include :

- sodium thiosulphate (applied at 80°C)
- glucose.

Adding complexing agents to the chroming bath
Lactic acid, other dicarboxylic and a-hydroxycarboxylic acids are also effective in reducing the concentration of the chromium (VI) in the bath. These form stable complexes with chromium ions and may adversely affect the concentration of the residual chromium (III) in the bath.

ALTERNATIVE METHODS OF CHROME MORDANTING

Alternative chromium (III) mordants:
- α-hydroxycarboxylic acids
- lactic acid
- 5-sulpho-salicylic acid
- maleic acid

Problems with alternatives:
- do not oxidise the wool-dye complex to develop the full colour
- are not suitable for deep blacks
- total chromium in effluent is unaffected.

Use of a chromium (II) complex

CR FACTOR AND METHOD	CHROMIUM LEVEL DETECTED IN EFFLUENT (PPM)
0.35 Dichromate – thiosulphate standard	12.0
0.35 Cr(III) complex	104.0
0.25 Cr(III) complex	53.6
0.20 Cr(III) complex	32.8
0.175 Cr(III) complex	24.6
0.15 Cr(III) complex	12.3
0.12 Cr(III) complex	11.5

9 - **Module 9:** Environmental impacts associated with dyeing wool

INDICATE THAT chromium (III) can be pre-complexed with:
- α-hydroxycarboxylic acid
- lactic acid
- 5-sulpho-salicylic acid
- maleic acid.

NOTE THAT the complex is added to the bath at the chroming stage instead of potassium dichromate to mordant the dye.

MENTION THAT a substantial amount of hydrogen peroxide must also be added to get full shade development and wet fastness. The peroxide presumably imitates the oxidising action of the potassium dichromate.

EXPLAIN THAT these alternative chroming agents eliminate the need for chromium (VI), but they:
- do not oxidise the wool — reducing the damage to the fibre
- cannot be used to form deep blacks
- do not affect the total chromium in effluent.

Alternatively, a lesser amount of potassium dichromate (0.6%) can be used five minutes after the chromium (III) complex has been added.

ALTERNATIVE METHODS OF CHROME MORDANTING

Alternative chromium (III) mordants:

- α-hydroxycarboxylic acids
- lactic acid
- 5-sulpho-salicylic acid
- maleic acid

Problems with alternatives:

- do not oxidise the wool-dye complex to develop the full colour
- are not suitable for deep blacks
- total chromium in effluent is unaffected.

Use of a chromium (II) complex

CR FACTOR AND METHOD	CHROMIUM LEVEL DETECTED IN EFFLUENT (PPM)
0.35 Dichromate – thiosulphate standard	12.0
0.35 Cr(III) complex	104.0
0.25 Cr(III) complex	53.6
0.20 Cr(III) complex	32.8
0.175 Cr(III) complex	24.6
0.15 Cr(III) complex	12.3
0.12 Cr(III) complex	11.5

9 - **Module 9:** Environmental impacts associated with dyeing wool

INDICATE THAT chromium (III) can be pre-complexed with:

- α-hydroxycarboxylic acid
- lactic acid
- 5-sulpho-salicylic acid
- maleic acid.

NOTE THAT the complex is added to the bath at the chroming stage instead of potassium dichromate to mordant the dye.

MENTION THAT a substantial amount of hydrogen peroxide must also be added to get full shade development and wet fastness. The peroxide presumably imitates the oxidising action of the potassium dichromate.

EXPLAIN THAT these alternative chroming agents eliminate the need for chromium (VI), but they:

- do not oxidise the wool — reducing the damage to the fibre
- cannot be used to form deep blacks
- do not affect the total chromium in effluent.

Alternatively, a lesser amount of potassium dichromate (0.6%) can be used five minutes after the chromium (III) complex has been added.

MORDANTING WITH ALTERNATIVE METAL SALTS

Alternative mordants:

- Iron (ferrous/ferric) salts used instead of traditional after-chroming methods
  - dolour difference
  - difference in fastness often lower

- Tannic acid combined with ferrous salts:
  - Improved fastness
  - No colour improvement

http://www.aurorasilk.com/natural_dyes/iron.html

http://dyeing-crafts.co.uk/product/16

10 - **Module 9:** Environmental impacts associated with dyeing wool

MENTION THAT alternative metal salts can be used as mordants. Called 'green vitriol' in old dye books, ferrous sulphate has a long history as a mordant. Aluminium salts were also used as mordants for natural dyes in ancient Egypt. Iron salts continue to be used as a mordant in craft operations.

EXPLAIN THAT the use of ferrous salts has been investigated as a possible method of eliminating chromium from chrome dye effluents. It has been noted that:

- aftertreatment with iron (II) and iron (III) salts gives different colours to mordanting with chromium
- light- and wash-fastness of dyeing with these salts is comparable with those obtained with the use of traditional aftertreatment methods using dichromate.

INDICATE THAT the use of tannic acid in combination with the ferrous salts can improve the fastness of chrome-type dyes further. However the problem of the colour of the dyeing not being the same as with chrome dyed wool means the approach has not been commercially adopted.

ELIMINATING CHROMIUM DURING DYEING

Lanasol CE (Huntsman)
- A reactive dye system introduced in early 2000s

Realan EHF (DyStar)
- A reactive dye system introduced in early 2014

Metal free dye ranges

DyStar®

11 - **Module 9:** Environmental impacts associated with dyeing wool

EXPLAIN THAT a number of metal-free reactive dyes have been especially developed for wool dyeing.

LANASOL CE dyes (Hunstman) are suitable for exhaust dyeing of untreated, felt-resist-treated wool (e.g., chlorinated and machine- washable) in all forms, especially loose stock, top and yarn. These dyes are claimed to:
- have excellent wet fastness properties
- be especially suitable for deep shades
- be applicable as replacement of afterchrome dyes.
- suitable for Oeko-Tex Standard 100
- have high exhaustion and fixation
- have excellent reproducibility
- be applicable in the iso-electric region of wool giving maximum preservation of wool quality to a range of wool types.

REALAN EHF dyes (DyStar) are likewise suitable for exhaust dyeing of untreated, felt-resist-treated wool (e.g., chlorinated and machine-washable) in all forms, especially loose stock, tops and yarn. These dyes are claimed to:
- be tinctorially strong
- have low AOX residuals
- reduce damage to the fibre during dyeing
- promote lower weight loss during dyeing
- improve spinning performance and yield
- have fewer ends down
- be suitable for Oeko-Tex Standard 100

MENTION THAT other metal free dye ranges with improved balance of levelling and fastness have also been developed by dye manufacturers. Some examples are the Cetolan AV dyes from Avoset and the Optilan MF dyes from Archroma. Although these dyes may not have the same performance characteristic as mordant dyes, they offer an alternative approach to eliminating heavy metals in dyeing effluent.

THE ISSUE OF BLACK

For wool, black has always been an important component of the colour range.

Since 1990s superblacks have been required for specific markets.

The problem dyes are:
- Mordant Black PV (Mordant Black 9)
- Mordant Black T (Mordant Black 11)

Super-black recipes require:
- up to 13% of these dyes
- a pre-chlorination
- a silicone after treatment.

12 - **Module 9:** Environmental impacts associated with dyeing wool

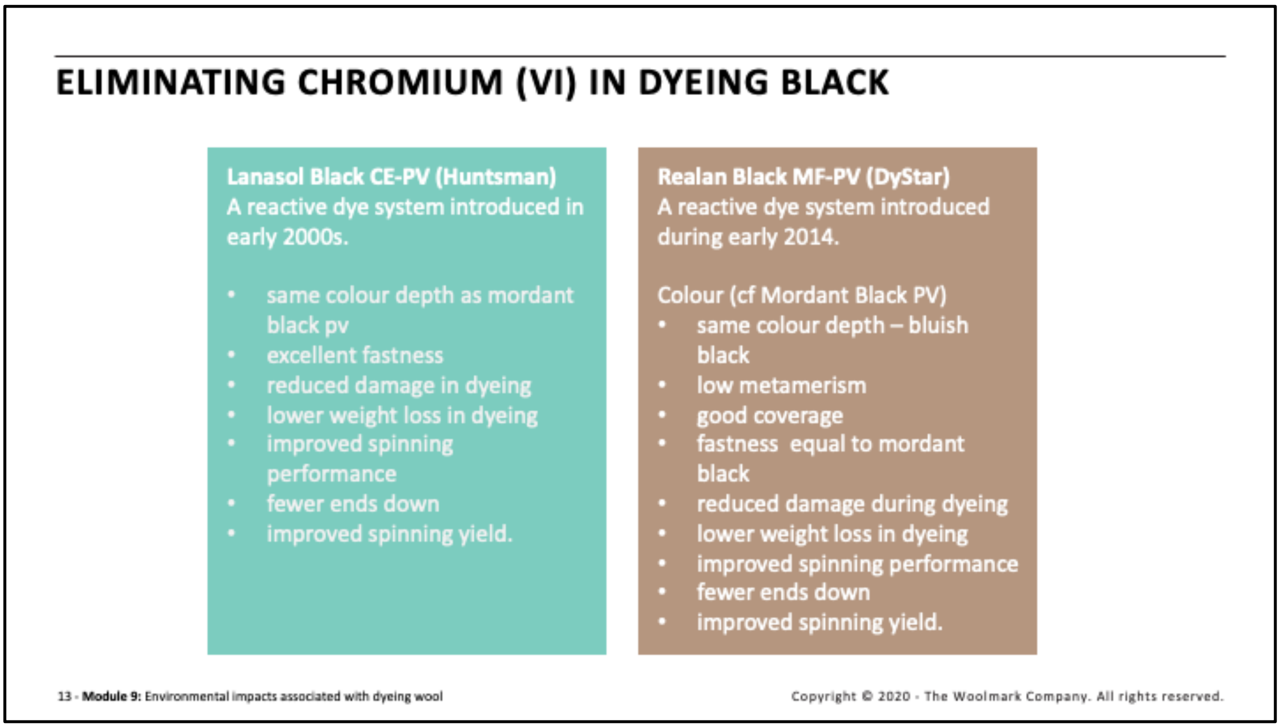
INDICATE THAT black has always been an important component of the colour range for wool apparel.

Since the 1990s superblacks have been required for specific markets — notably Japan.

Superblacks are traditionally achieved using:
- Mordant Black PV (Mordant Black 9)
- Mordant Black T (Mordant Black 11).

NOTE THAT these dyes have been difficult to replace. Until recent times, no other dyes gave the intensity of black required by superblacks.

MENTION THAT to achieve superblack, recipes have used up to 13% chrome black dyes combined with a pre-chlorination and a silicone aftertreatment. This results in high level of chromium in the dyeing and rinsing effluents.



EXPLAIN THAT recent developments have seen Huntsman and DyStar introduce reactive dyes that are claimed to achieve superblack dyeings without the need for chromium.

The dyes to replace Mordant Black PV (Mordant Black 9) include:

- LANASOL Black CE-PV (Huntsman)
- REALAN Black MF-PV (DyStar)

The dyes to replace Mordant Black T (Mordant Black 11) include:

- LANASOL Black CE (Huntsman)
- REALAN Black G (DyStar)

NOTE THAT claims for dyes used to replace chrome black dyes include:

- excellent wet fastness properties
- especially suitable for deep shades
- suitable for Oeko-Tex Standard 1 00
- high exhaustion and fixation
- excellent reproducibility
- application in the iso-electric region of wool.

AOX IN DYEING EFFLUENT

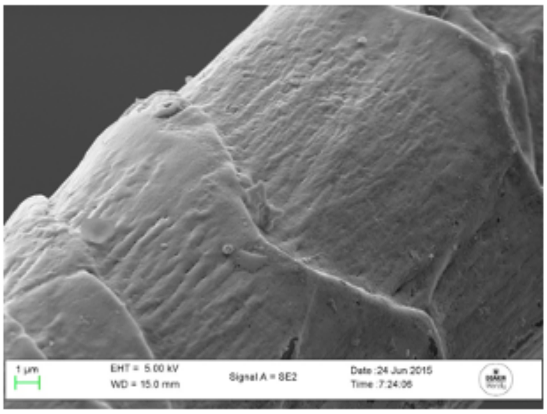
AOX — adsorbable organic halides

Formed primarily by the reaction of chlorine with wool proteins during felt-resist treatment.

- Felt-resist-treated wool is normally dyed with reactive dyes.
- Soluble organochlorine proteins leach from wool during dyeing (AOX) to form contaminant in dyeing effluent.

Limits imposed by regulators <12ppm China

Removal requires specialised methods.



Electron micrograph of treated fibre

14 - **Module 9:** Environmental impacts associated with dyeing wool

EXPLAIN THAT AOX or adsorbable organic halides is a term used to describe a type of pollutant that is an organic molecule containing one or more fluorine, chlorine, bromine or iodine atoms.

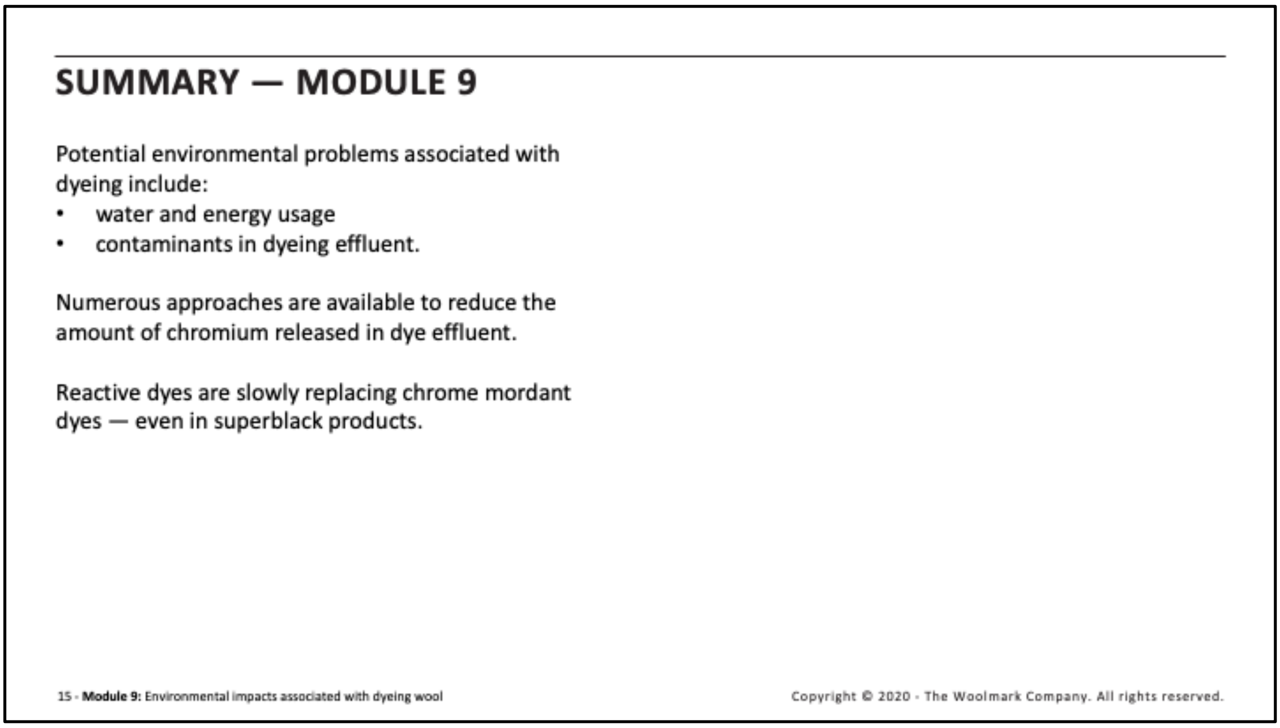
Limits are imposed by regulators on the maximum concentration of AOX allowable in mill effluent. In China this figure is around 12ppm .

POINT OUT that these compounds are formed when wool is felt-resist treated using chlorine — the most common felt-resist processes. Chlorine reacts with the protein molecules to form AOX materials.

INDICATE THAT not all the AOX-type proteins are removed from the fibres during the soluble protein extraction, which is part of the felt-resist process. Any un-cross-linked Hercosett polymer (an epichlorhydrin-reactive polyamide) which remains soluble can also be detected as an AOX material.

EXPLAIN THAT during dyeing some protein molecules that have reacted with chlorine but remained on the fibre in the felt-resist processing and some Hercosett polymer are extracted. These form the AOX contaminant in the dyeing effluent.

NOTE THAT some reactive dyes also can register as AOX materials.



SUMMARISE this module by explaining that there are a number of potential environmental challenges associated with the wool dyeing process. These include:

- water and energy use
- contaminants in dyeing effluent including:
    - surfactants with high aquatic toxicity
    - early stage processing chemicals
    - dyeing auxiliaries
    - dyes
    - prohibited or prescribed pollutants
    - salt
    - acid or base used for pH control
    - mordants.

REITERATE THAT most of these challenges can be controlled during the dyeing process.

REMIND participants that a number of methods have been developed to reduce the amount of chromium (especially Cr (VI)) released in dye effluent, including:

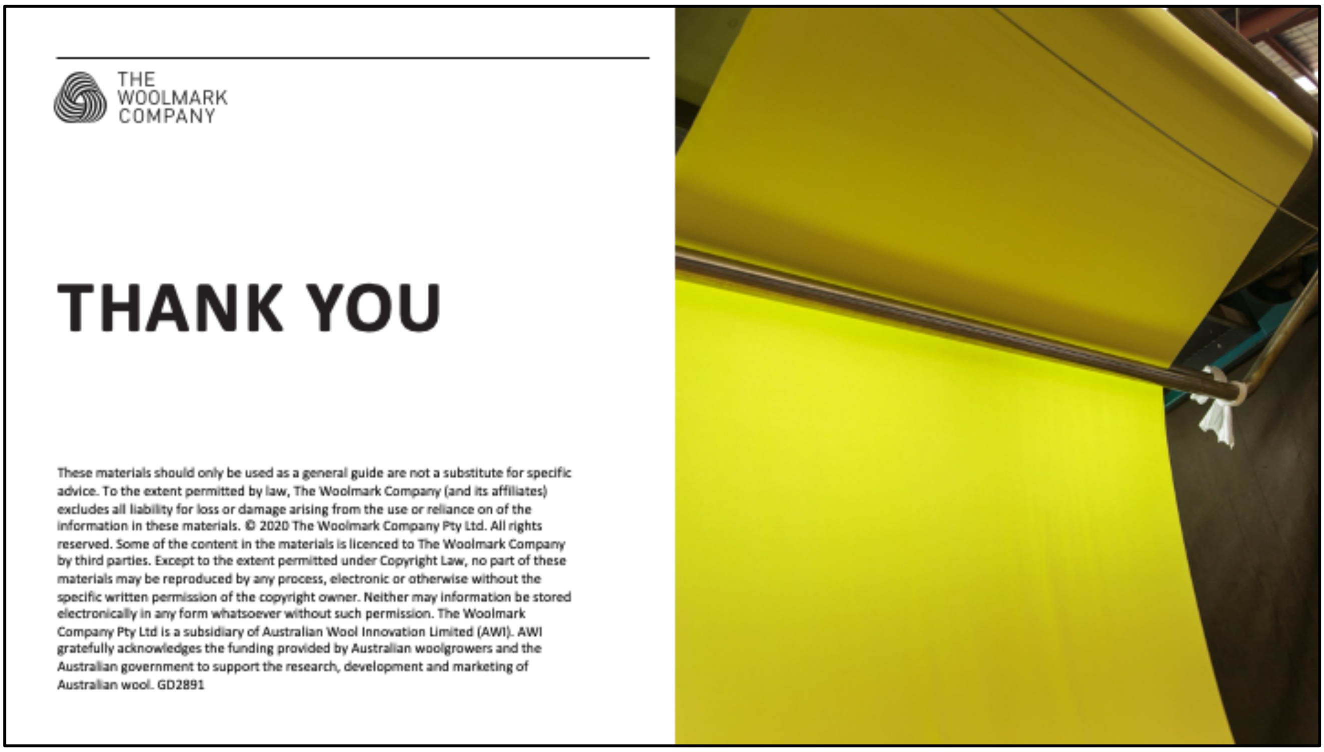
- optimising process conditions
- adding a reducing agent to the mordanting bath
- adding complexing agents to the chroming bath
- alternative chroming methods.

REVIEW the fact that a number of manufacturers have developed ranges to reduce or eliminate the need for chrome mordant dyes, including:

- reactive dyes, which appear to be gaining usage even in difficult areas, such as superblacks
- metal-free acid dyes with the required fastness and levelling properties.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*



INFORM participants that this module completes the Wool Science, Technology and Design course *The dyeing of wool.*

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today’s lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

THE
WOOLMARK
COMPANY

woolmark.com