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STRENGTHENING OF THE RAMIE TECHNOLOGY DEVELOPMENT CENTRE, CHANGSHA, HUNAN PROVINCE

DG/CPR/85/057 11-53/J13102

Final Report

Prepared for the Government of China by the United Nations Development Organisation, acting as executing agency for the United Nations Development Programme

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* The document has not been edited.

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Strengthening Of the Ramie Technology Development Centre, ChangSha

Final Report

1. Introduction

This is the final report covering weaving-related aspects of this UNDP project. It describes events during the period August 1993 and May 1994. During this time the author made two three week trips to the Ramie Technology Development Centre (R.T.D.C.) and Mr. Ye, a technologist from the centre spent five months at Bolton Institute.

The main body of this report describes progress in the eleven projects listed below, which were proposed in the author's previous report of the 5th August 1993.

Project 1 Sizing Materials.

Project 2 Process Control in Sizing.

Project 3 Optimisation of Weaving Settings.

Project 4 Design and Fabrication of Loom Attachments.

Project 5 Use of Loom Attachments.

Project 6 Application of Rapier Looms.

Project 7 Enhancement of Mr. Ye's Knowledge.

Project 8 Enhancement of Mr. Ye's Research Skills.

Project 9 Process Control During Yarn Preparation.

Project 10 Weaving Trials at ZhuZhou Mill.

Project 11 Enzymatic Treatment of Warp Yarn.

2. Mr. Ye (Projects 7 and 8)

These projects were aimed at enhancing Mr. Ye's knowledge of factors relevant to improvements in the preparation and weaving of fine ramie fabrics, and at enhancing his research skills.

The time scale of the UNDP project meant that the author was scheduled to return to ChangSha just one week after Mr. Ye's arrival in Bolton. Some of that week was spent ensuring that Mr. Ye settled in satisfactorily (accommodation, bank account, introductions to Institute staff, other researchers, other Chinese students, etc.), and the remainder setting up a project that he could conduct, without supervision, during the time the author was to be away. To this end, Mr. Ye was introduced to the facilities available in the Institute library, in particular the computerised search facilities, World Textile Abstracts, relevant textile journals and texts, and given instruction on how to conduct a literature search. He was then set the task of producing a review on the winding, warping, sizing and weaving of fine plain weave fabrics woven from staple yarns, with particular reference to ramie.

The first draft of the report was ready for the author's return, and was impressive in terms of its comprehensiveness and the sheer hard work which must have gone into its production. This was the first major report Mr. Ye had ever had to produce in English and it does him credit. After discussion of some of the finer technological points, and two editing sessions, the finished report resulted. The editing sessions were used to improve the syntax and vocabulary as a means of furthering Mr. Ye's command of written English, not at converting it into a report which reads as though written by an English student. The first draft contained numerous phrases which had a 'Chinese' flavour to them. These were discussed but only changed where the meaning was obscured: it is, after all, Mr. Ye's report. This report, entitled "Considerations On Ramie Weaving", is included as appendix 1.

The first two months of Mr. Ye's stay in Bolton were mainly taken up by the production of the above report, and the following three months by research into sizing materials. The research project, which is described in part three of this report, proved an ideal medium for the development of Mr. Ye's research skills for several reasons: it involved collaboration with an industrial partner and another educational establishment; account had to be taken of the possible effects of differing conditions, for example the use of a different loom; unforeseen difficulties arose which required new strategies to be devised which did not compromise the integrity of the research; and several indicators of performance were used and evaluated.

In addition to the two activities outlined above, which comprised the main vehicles for achieving the aims of projects 7 and 8, the four below were also beneficial.

Mr. Ye attended a series of seminars held by the Institute for research students. Whilst aimed at full-time research students who are registered for postgraduate qualifications, they cover such topics as research methodology, study skills, time management and presentation of seminars which are useful to anyone engaged in research.

Mr. Ye participated in the final stage of the project undertaken during the author's second visit to ChangSha. This required analysis techniques which were new to him and different to those used for his main research project.

Few of the topics covered in timetabled sessions in the School of Textiles were of direct relevance to Mr. Ye's research, and his other activities precluded his attending many, however he did attend some which were either relevant or of general interest.

Ramie is not processed in the United Kingdom, however it was considered of value for Mr. Ye to visit several textile companies so that he could compare their organisation and working practices with those prevalent in the Chinese ramie industry. Companies visited were:

Priest Lindley Ltd.	Huddersfield
Ames Ltd.	Westhoughton
Skopos Ltd.	Dewsbury
JH Birtwhistle Ltd.	Haslingden
Dataweave Ltd.	Marsden (a seminar to launch a new loom)

The above describes how the aims of projects 7 and 8 were met during the prescribed time period, August 1993 to January 1994, but, of course, Mr. Ye's involvement in all stages of projects 2, 4, 5, 6, and 9 during February and March 1994 also contributed to the development of his knowledge and research skills.

3. Weaving (Projects 3,4,5,6, and 10)

3.1 Project 3 Optimisation of Weaving Settings

The aim of project 3 was to find the settings for the 1515 loom which yielded the best combination of weaving efficiency and fabric appearance. Most of this project was conducted by the author during his second visit to the R.T.D.C. with the assistance of Mr. Xie and Mr. Bing, since Mr. Ye was in Bolton. One disadvantage of this was the time required to explain the purpose and methodology of the experiment to Mr. Bing, who has halting English, and Mr. Xie,who has none. However, it did establish that the R.T.D.C. has at least two more keen and capable weaving technologists. Mr. Bing has only recently joined the Centre and shows great promise. The final part was conducted at the School of Textiles in Bolton with the assistance of Mr. Ye.

3.1.1 Preliminary Work

The first step was to gait a warp into the cam loom and ensure that all loom settings likely to affect the results were correct. Mr. Bing and Mr. Xie gaited the warp, and performed the settings which were then checked, and in some cases adjusted, by the author. Observation of the methods used, together with later observations at ZhuZhou Mill, revealed some simple and slight modifications to procedures which will enable more accurate settings to be made. These are described in the manual which comprises appendix 27.

The displacements of the heald shafts and back rail were measured and are shown in appendix 2. The heald shaft displacement is typical for shuttle looms designed for weaving spun yarns. Two thirds of the loom cycle are used for heald shaft movement, the heald shafts dwelling for the remaining third. The back rail displacement curve established that it would be possible to use a setting at which the back rail was at its rearmost position 60° after the healds had crossed, a setting required for three of the proposed samples.

Appendix 2 also shows the distribution of tensions across the warp whilst the loom was running. The distribution is typical: low at the edges, rising to the centre and erratic in the temple regions. The very low tension recorded for one end suggests that this end had previously been clinging and had been released shortly before the measurement was made. The tension distribution pattern confirmed that unwanted variables had not been introduced by the use of incorrect settings or by faulty beam build.

3.1.2 Experimental Variables

The variables proposed in the report dated 5th August 1993, which followed the author's first trip to ChangSha are reproduced in appendix 3. Those used are contained in appendix 4. They differ for six reasons:

1. The original heald timings of 290° and 310° assumed that the dobby loom, in which the healds do not dwell, would be used. The availability of the cam loom meant that 300° and 330° could be used instead. 330° was the latest timing possible whilst ensuring that the warp tension was at a maximum at shuttle entry.

2. It proved inadvisable to weave with a backrest setting of 7.5 cm (the setting recommended in the 1515 manual) since the ends in the top shed position were so slack that they broke frequently due to interference by the shuttle, and there was some danger of the shuttle being deflected and flying out of the loom. Just enough fabric was woven to allow samples to be prepared for assessment of reediness.

3. A backrest setting of 12.5 cm would have required considerable modification to the means of mounting the warp stop motion. A minor modification permitted a setting of 12 cm.

4. It proved possible to weave with a reduced warp tension at low backrest settings. Extra samples were woven using the reduced settings.

5. Observations made whilst weaving samples with backrest settings of 10 cm and 12 cm led to the conclusion that samples having backrest settings of 8.5 cm and a healds level timing of 330° would not yield useful data. Consequently, these were not woven.

6. Due to the time taken to gait a warp and repair several minor mechanical failures which occurred during the early part of the experimentation the sample length was halved after the first three samples had been woven. This did not affect the validity of the results.

3.1.3 Experimental Procedure

Before each sample was woven the appropriate settings were made, checked and a 10 cm length of fabric woven in order to allow the warp tension to stabilise. The loom was operated by experienced weavers. During weaving the cause of each stoppage was identified, noted and the position marked on the fabric. In addition, the amount of clinging in the back shed was judged four times for amount and position.

As soon as the sample was woven the static warp tension was measured and recorded for two ends (the same two in each case) at 20° intervals over two loom cycles.

Once all of the samples were woven they were removed and inspected for faults.
Two 21cm square samples were cut, one from the left hand side and one from the right hand side, of each of the 15 large samples and also from four fabrics selected at random from stocks which had been passed as satisfactory at ZhuZhou Mill. Care was taken to avoid inclusion of any obvious faults. The samples taken from the left hand side of each fabric were independently assessed for reediness by Mr. Xie, Mr. Bing and the author. Those from the right hand side were desized, scoured and bleached in the School of Textile Studies by Mr. Ye and subsequently assessed for reediness by Mr. Ye and the author.

For the purposes of assessment of reediness the samples were randomly assigned code letters and viewed with the letters face down. Subjective assessment of reediness is not possible with as many as nineteen samples at the same time due to viewer fatigue, so a technique was used which allowed a preliminary assessment with group sizes of two or three. This allowed the samples woven at R.T.D.C. to be divided into five groups, the members of a group displaying approximately equivalent reediness. One member of each group was selected together with the best and the worst of the ZhuZhou samples. The resulting seven samples were assessed again on the next day to establish a rank order, and that order compared with that of the previous day to ensure consistency. The equivalent seven samples taken from the right hand side were assessed in the bleached state.

3.1.4 Results and Discussion

The following discussion makes reference to the mechanisms which cause reediness and clinging of ends. These were explained in the author's previous report, which should be referred to if necessary. The values obtained for the six parameters are contained in appendices 5 and 6.

The four sets of curves contained in appendix 5 illustrate the effects of varying the healds level timing, the backrest setting, the position of the tension weight and the timing of the back rail cam. Delaying the healds level timing in 30° increments had no clearly discernible effect on the end tension level, apart from possible increasing the minimum tension level as the healds crossed, but clearly caused a corresponding delay in the times at which the tension rose and fell due to movement of the healds. It is important that the maximum tension level is reached before the shuttle enters the shed so that there are no clinging ends which might interfere with its flight. This condition is achieved at all three healds level timings, but the healds level timing also affects the level of reediness.

Raising the backrest (given by reducing the setting value) clearly increases end tension in the lower shed position and decreases tension in the upper shed position. This has pronounced effect on reediness and the likelihood of ends clinging.

Moving the tension weight from position 5 to position 4 increased tension in both the lower and upper shed positions by about 13%. The tension when the healds were level was increased by a greater percentage. The tension in all three of these positions is important, for different reasons. The maximum tension occurs in the lower shed position and any further increment may increase the warp breakage rate. An increase in end tension in the upper shed position and/or an increase in the tension as the healds cross means that the likelihood of ends clinging is reduced.

Delaying the timing of the back rail cam to 60° beyond that of the time that the healds were level tended to increase end tension in both upper and lower shed positions and also had the rather surprising effect of delaying the fall in tension without affecting the rise in tension.

Table 1 in appendix 6 shows the values obtained for the other parameters. The figures in columns 6 and 7 are the subjective assessments made during weaving of the quantity and position of clinging ends in the rear shed. A high figure in column 6 indicates that more ends clung and the fractions in column 7 refer to the point at which most ends clung as a fraction of the distance between the warp stop bars and the rear heald shaft. In both cases a high figure is undesirable. Not all samples were rated for clinging position since it only became apparent that this would be valuable part way through the experiment.

It is clear that more clinging occurred when weaving with a raised backrest and that the clinging was closer to the heald shafts (a low value for the back rail setting means that the back rail was set higher). This is due to the low tension occurring in ends in the upper shed position, and is in agreement with the mechanism put forward in the author's report of 5th August 1993. A late shed timing also increased the frequency of clinging. This was not anticipated.

A likely explanation is that it is due to the effect of healds level timing on end tension at beat-up. During beat-up the end tension rises as the reed strikes and displaces the fell causing a shock loading of the ends. If this occurs when the end tension is already high due to an early healds level timing, clinging ends are more likely to separate. Sample J is anomalous in having a clinging position close to the healds at a low backrest setting. The reason for this is not clear, but the same effect had been observed when weaving samples E and K, so it is assumed to be related to the delayed back rail cam timing.

Columns 8 to 14 show the frequencies of warp breakages during weaving and those faults in the woven fabric which are considered to be relevant to the discussion. When analysing these it should be noted that the lengths of samples D,E and J were approximately double those of the remaining samples.

The warp breaks are classified by cause. Columns 9 and 10 include warp breaks which were caused by yarns faults and crossed ends. These causes originate prior to weaving, and whilst it might be argued that the existing deficiencies might be exacerbated by the settings used, the case is far from clear. However, their incidence is directly relevant to parts 4 and 5 of this report. When considering the frequency of warp breaks due to tension, given in column 8, which are related to the settings under investigation, it should be remembered that the sample lengths were short and the ambient conditions were not favourable to ramie weaving. The percentage relative humidity was in the low 60's whereas in ZhuZhou mill atomised water is sprayed into the air to ensure that values of over 80% are achieved. This last point is especially significant since the tensile properties of ramie improve under humid conditions. This also means that the breakage rates should not be compared to those recorded under mill conditions, included in section 3.2 of this report. Nevertheless, it seems clear that a raised back rail increased the warp breakage rate. There are two reasons for this: a raised back rail increases the tension in the lower shed position, and hence the maximum tension acting on the ends; and the greater incidence of clinging would further increase the tension in those ends which clung.

The cracks referred to in columns 11 to 13 are those faults described in the author's previous report as being the result of localised disturbances in the cloth fell position which arise from ends clinging in the rear shed. Weaving over, the occurrences of which are recorded in column 14, can occur when ends cling in the front shed. Appendix 7 contains examples of these faults which were removed from samples during inspection. Since these faults are caused by clinging ends it is not surprising to see their incidence increase with a raised back rail and an early healds level timing.

Appendix 8 shows two faults which were also caused by clinging ends. In both cases the clinging was caused by yarn faults and persisted until four or five centimetres from the rear heald shaft. The first fault was caused by two clinging ends and takes the form of a warp way crack. In the second example 9 or 10 ends clung resulting in a pronounced repped effect, the picks not returning to a straight configuration for several centimetres.

Columns 15 and 16 in appendix 6 show the results for the seven samples which were shortlisted for assessment of reediness. The main figure is the rank order, 1 being the least reedy, i.e. the best. The figures in brackets are the total scores for each sample. The loomstate samples were assessed by three judges and the bleached samples by two, giving best (least reedy) possible scores of 21 and 14 respectively.

All judges agreed that sample N, which was the only sample woven with a back rail setting of 7.5 cm, was clearly the best in both the loom state and bleached conditions. The ranking of the other samples was the same for both conditions except for the second ZhuZhou Mill sample which fared worse when bleached. This was probablv because the loomstate samples taken from ZhuZhou mill were noticeably whiter than the samples woven at R.T.D.C. This was one of the motivations for desizing, scouring and bleaching the samples, the other being that reediness tends to diminish during wet processing. The five samples woven at R.T.D.C. agree with accepted theory: a raised back rail combined with an early healds level timing causes least reediness, a lowered back rail with a late healds level timing causes most reediness, and intermediate settings give intermediate levels. The best sample from ZhuZhou mill was equivalent to the best sample woven at R.T.D.C. whereas the worst was only slightly better than the worst sample woven at R.T.D.C.

3.1.5 Conclusions

The aims of this series of experiments were to find the optimum settings for weaving fine plain weave fabric from ramie yarns, i.e. those which gave the best compromise between weaving efficiency and fabric appearance without the use of additional devices. It is clear that one cannot have the best of both worlds: an excellent reediness rating was only obtained by using settings which made the upper shed so slack that to continue weaving was inadvisable. It was possible to produce fabric with a reediness rating which was better than three and equivalent to the fourth sample randomly selected from ZhuZhou Mill stock, however, the settings employed increased warp breakage rates, the occurrences of cracks in the fabric, and weaving over. Whether the warp breakage rate which would obtain from using these settings under mill conditions would exceed that which occurs at ZhuZhou Mill using more favourable ambient conditions and lease rods cannot be predicted. It was decided that this should only be investigated if projects 4 and 5 yielded unfavourable results.

3.2 Weaving Studies at ZhuZhou Mill

One day was spent at ZhuZhou Mill during the author's visit of August 1993 and a further three days during March 1994. The August visit was devoted to a detailed production study of four looms and a day was spent examining loom settings and their effects during the second visit.

3.2.1 Production Study

3.2.1.1 Study conditions

A production study in weaving consists of observing a weaver's complement of looms and recording the cause of each stoppage. This gives a detailed picture of weaving conditions, albeit on a limited number of looms. A weaver's complement in ZhuZhou Mill is four looms. Looms 241 - 244 were observed for a total of three hours, two during the morning and one during the afternoon. There were two reasons for conducting the study: to see what problems arose in mill conditions, and to see if the causes of warp stoppages were similar to those experienced at the R.T.D.C. Conditions would have differed if the warp at R.T.D.C. was atypically well or poorly prepared.

The conditions during the production study were not entirely representative of ZhuZhou Mill in that the weaver's complement was abnormally low. As stated above, a weaver tends four looms. In addition a helper weaver tours several weaver's complements helping with serious stoppages. During the first hour of the study both the helper weaver and Miss Zao spent all of their time on the looms being studied; during the second hour Miss Zao left but the helper weaver spent most of her time on the four looms; during the hour in the afternoon (some three hours had elapsed since the morning's studies had ended) only the weaver remained, the helper weaver being present for less than ten minutes. In addition, the weavers are unused to production studies, and their rating during a work measurement would certainly have exceeded 100. The net result was to decrease the length of time looms were waiting for attention, and hence increase the amount of time that the looms were running, which in turn increased the number of stoppages. However, the amount of time available to inspect the warp threads and prevent warp stoppages was also increased. The increase in weaving efficiency can very roughly be estimated using the number of occurrences in the column headed 'stop on change'. These figures are equal to the number of pirns woven. They averaged 11 during the first hour, 9.5 during the second, and 7.25 during the third. If the third hour is assumed to be typical, the increases in efficiency would have been of the order of 27%. Fortunately the increase in efficiency does not invalidate the study since it is the cause of stoppages and the their relative, rather than absolute frequencies, which were of interest.

3.2.1.2 Results and discussion

The results are tabulated in appendix 9. Columns 2 to 7 give the number of occurrences of short stoppages. Columns 8 to 11 record the number of minutes stopped for the eleven long stoppages which occurred during the study. Columns 1 to 3 show warp stoppages attributed to the same three causes as in appendix 6: warp break, yarn fault and crossed end. As before, the latter two causes are due to faulty yarn preparation. Columns 4 and 5 are also warp stoppages due to yarn preparation. Column 4 records times when the weaver stopped the loom in order to disentangle badly crossed ends, and column 5 when the loom stopped because an end was not continuous, probably due to a breakage during warp sizing.

Column 8 shows that weft breakage was a relatively minor cause of stoppages. Column 9 is very significant. The 1515 is an automatic loom in that the shuttle is automatically changed just before the pirn is emptied of weft. A 'stop on change' normally refers to an instance when the process fails and the loom stops because there is no weft. However all of the shuttle change mechanisms on the looms studied had been deactivated by the weaver since they were malfunctioning, and hence the weaver had to stop the loom and change the shuttle manually. This had three serious effects. Firstly, changing shuttles became a major item of work for the weaver - four malfunctioning units would mean that the workload would exceed that which is possible at any reasonable efficiency. Secondly, the weaver was not always able to stop the loom before the weft ran out, necessitating a pickfinding operation which frequently resulted in a weft bar. Finally, the time spent changing shuttles should have been spent inspecting warps and preventing faults from occurring. It was considered to be too late in the day to investigate this problem as part of this U.N.D.P. project, but it was discussed with Mr. Xu and suggested that a technologist at the centre do so.

A final point should be mentioned which, although not part of the brief for this project, should be mentioned is that the weavers did not use hearing protection. Apparently protection is provided but the weavers are reluctant to use it. The relationship between long term exposure to loom noise and hearing loss is well established and the importance of educating the work force and ensuring that they use hearing protection cannot be over emphasised.

3.2.1.3 Comparison with ZhuZhou production studies

The results and implications of the production study were discussed in detail with Miss Zao during the author's third and final visit to ZhuZhou Mill. It transpired that production studies for the fabric in question are carried out at ZhuZhou Mill at the rate of four looms for one hour per month. The results for the first three months of 1994 i.e 12 loom hours, the same duration as the studies conducted by the author, were made available and are summarised in appendix 10. The classification of causes differs slightly from the author's, thus the causes are grouped and the equivalent classification given. Weft breaks occurred less frequently, and there were no stops on change, however Miss Zao stated that 30% would be a normal figure for the latter. Given the difference in classification and difficulties in translation, the causes and proportions of warp stoppages are broadly similar. If one assumes that during the production studies conducted by ZhuZhou staff weaving efficiency was not artificially enhanced, and was equal to that given in the previous report (46%). one can estimate that 1.7 warp breaks occurred per metre of fabric in the ZhuZhou study compared with 1.81 during the author's study. It can thus be concluded that agreement is good.

3.2.1.4 Comparison with project 3

The conditions under which project three was conducted at the R.T.D.C. were very different from those existing in ZhuZhou Mill. The settings were more precise, and some were more favourable. On the other hand, the relative humidity in the weaving room at the R.T.D.C. was between 60% and 65%, compared with a range of 80% to 85% in the Mill. Low humidity is a considerable disadvantage when weaving ramie, in fact ZhuZhou Mill would not attempt to weave at such low values. In addition the loom was frequently stopped for extended periods of time. In view of these differences it is perhaps surprising that the warp stoppage rate was as low as 3.4 stops per metre of fabric, about double that of the production studies. It is significant that the causes are similar, had they not been then the validity of conducting projects 3,4 and 5 at the R.T.D.C. would have been called into question.

3.2.2 Investigation into loom settings.

The aim of this investigation, which was conducted by Mr. Ye and the author during their visit to ZhuZhou Mill in March 1994, was to establish the consistency of those loom settings which affect reediness, cracks, weaving over and warp breakage rates. The positions of the backrest, stop motion and let-off motion weights were checked on twenty four running looms, and the healds level timing and shed setting on eight of the twenty four looms whilst they were stopped. The results are shown in appendix 11.

The heights of the back rail, the warp stop motion and the heald shafts, and the time that the healds are level are the loom settings which have the greatest effects on reediness and cracks in the fabric. They should ideally be exactly the same on each loom, but in reality small variations are practically unavoidable on a loom such as the 1515. However, realistic tolerances should be established which acknowledge these limitations but do not cause either problems in weaving or differences in fabric appearance. Recommendations are made in Research Report 3.

The back rail settings varied between 70 mm and 75 mm, 75 mm being the recommended setting in the manual. This is an accessible and easy to measure setting, and there is no reason why the values should not be within 2 mm of the standard. On the whole this setting was sufficiently accurately made, but two looms,361 and 367, gave cause for concern as the differences in settings between the two sides of the loom were 5 mm and 3 mm respectively.

The stop motion height is less easy to measure, although a gauge is used. The range of settings was much greater, 22 mm, with 10 of the looms exhibiting side to side variations in excess of 2 mm.

The distance from the stop motion to the back rail has a lesser effect, but is easier to measure. The range of settings, 25 mm, was greater than for stop motion height and there was also greater side-to-side variation.

The range of healds level settings, 13 mm, represents approximately 10 degrees of crankshaft rotation at the relevant part of the loom cycle. ±4 mm would seem a reasonable tolerance. Half of the looms measured showed a difference in setting between the two sets of cams which are fitted. The procedure suggested in appendix 27 should avoid both this and the incorrect heald height settings shown in the final column of the table.

The setting which showed the greatest variation was the position of the let-off motion weights. Upon enquiry, three reasons were given for the variations: firstly, the let-off motion does not compensate accurately for the decreasing package diameter from a full to an empty beam, and the weight must be moved to compensate; secondly, additional weight would be applied if the warp showed a greater tendency to cling; and finally, it is believed that applying a different amount of weight to each side will compensate for a warp which tends to be slacker at one side than the other due to faulty beam build (or side-to-side variations in cam settings or the heights of back rails, warp stop motions or heald shafts!). Whilst the first reason is always a possibility with fairly primitive let-off motions, and the second is true, the third is a fallacy. Compensation is only possible if the back rail is able to bend or twist. If this were so it would not be a serviceable back rail.

It was decided to measure the effect of the weight setting and the package size on warp tension. Lack of time precluded measuring all twenty four looms, so the damped and peak tensions were measured for four ends on six looms. Two looms had very low settings, two had very high settings and two had medium settings. The results are contained in appendix 12.

There are insufficient observations to enable many firm conclusions to be drawn, but the package size does seem to have some effect and there is certainly a large variation in the average tensions produced by the highest and lowest settings. The highest settings produced damped and peak tensions which were respectively 1/3 and 1/5 greater than those produced by the lowest settings.

Control of warp tension is critical to end breakage rates, warp and weft crimp balance in the fabric, fabric dimensions, and behaviour during finishing. If warp tension is to be accurately and consistently applied it is vital to understand the behaviour of a warp let-off motion throughout the range of its settings and the full range of package diameters. This is a lengthy investigation and could not be completed in the time remaining to the U.N.D.P. project; accordingly an experiment has been devised for completion at a later date. The details are included in appendix 24.

A further observation was that the positions of the lease rods used in ZhuZhou to restrict the length of the back shed varied considerably. The positions of the first lease rods varied between 6 cm and 9 cm from the final row of warp stop pins, and the second between 8 cm and 20 cm from the rear heald shaft. The reason for the variation is straightforward, if a weaver observes that a warp is clinging excessively she (all of the weavers were women) positions the rods closer to the rear heald shaft in order to further restrict the shed. It was obvious that the effects on warp tension should be established, but it was decided to do this under controlled conditions at the R.T.D.C.

3.2.3 The application of rapier looms (Project 6)

It was stated in the author's previous report that the Chinese-made rapier looms recently installed at ZhuZhou Mill are more likely to successfully weave ramie warps than the Somet loom installed at the R.T.D.C. To date, only cotton/ramie blends have been trialed on the rapier looms, and during the author's final visit to ZhuZhou Mill the looms were not in use. This precluded experimental work but did allow a close inspection. This inspection revealed that the aspects of loom design which are of relevance to this project, i.e. the sley and heald movement, the setting possibilities of the back rail and the warp stop motion, and the mounting possibilities for warp restrictor rods are the same as the 1515 shuttle loom. The rapier loom is, in effect, a shuttle loom conversion.

The design speed of the loom is 200 picks min^{-1}, modest for a rapier loom but 33% faster than the fastest 1515 loom. Technologists at ZhuZhou Mill feel that this is too fast for 36 Nm ramie warps. This is certainly true with the current standards of yarn preparation, but not, in the author's opinion,if the improvements in yarn preparation processes envisaged in projects 1, 2 and 9 are realised. The chief advantage of the rapier loom is not an increase in production speed but the reduction in weaver's workload and fabric faults which result from eliminating the need to change shuttles. A second advantage is that the rapier loom is designed to weft mix, i.e. to insert picks alternately from two packages. This helps to mask faults which arise from package to package variations in yarn characteristics.

It is important that ramie warp trials on the rapier looms do not commence until the expected improvements in yarn preparation are realised, and performance on the 1515 loom is optimised. Trials will thus not occur in the lifetime of this project, but are strongly recommended when the time is right.

3.2.4 The design and use of warp restrictor rods (Projects 4 and 5)

These projects were given the highest priority during the author's final visit to ChangSha. Project 3 had already established that, without the use of additional devices, those loom settings which produce minimal reediness also generate cracks and a high warp stoppage frequency. In ZhuZhou Mill the use of lease rods largely eliminates cracks but places excessive stress on the warp threads, and their somewhat haphazard application and action fails to produce minimal reediness. The proposed warp restrictor rods would, if successful, restrict the shed in a controlled manner whilst avoiding the drawbacks of lease rods, and also permit a more precise control of reediness.

3.2.4.1 Basic design

The design of the warp restrictor device had to satisfy the following criteria:

1. It should restrict the rear shed by placing a rod above and a rod below it.

2. It should be capable of precise adjustment in three planes: vertically to allow a difference in tension of ends in the upper and lower shed positions in order to minimise reediness; closer to and further from the front of the loom in order to eliminate cracks; and from side to side in order to compensate for differing lateral positio . . of warps.

3. It should be simple and cheap to manufacture.

4. It should be capable of application without engineering modifications to the loom.

5. It should not unduly restrict weaver access to the warp threads.

6. The prototype should be capable of rapid manufacture in order to allow its application during the author's stay.

The prototype device was designed, manufactured and ready for application within three days. The requirements and basic design were established by Mr. Ye and the author; Mr. Ye drew the plans; the parts were manufactured by hand in the R.T.D.C. workshop; and the necessary fine tuning carried out by Mr. Bing, Mr. Ye and the author.

Appendix 13 contains photographs and sketches of the device, and two minor modifications which proved advantageous during use. The prototype consisted of a frame constructed from five pieces of angle iron and two steel tubes which were the restrictor rods. Ideally the rods would be chrome plated and free to rotate, but for the sake of expediency two existing galvanised tubes were used instead. The tubes were rubbed smooth with emery cloth, internally threaded and locked into position with bolts. In all other respects the device fulfilled the original intentions.

3.2.4.2 Experimental variables

These are detailed in Appendix 14. The results for the position of clinging ends from project three suggested that placing the restrictor rods half way between the warp stop motion and the rear heald shaft would reduce clinging sufficiently to avoid an unacceptable level of cracks in the fabric. This position was used for all samples. Initially four restrictor rod heights were used with a healds level timing of 270°. Additional samples were woven to investigate the effects of a later healds level timing (290°), a higher back rail position (10cm), and a change in the tension weight setting.

There were two unwanted variables about which nothing could be done. One was the difference in ambient conditions in the weaving room at the R.T.D.C. in March 1994 from those that existed during August 1993. The experiments were conducted in temperatures which varied from 10° C to 12° C and a relative humidities of between 60% and 80 %. The second was the fact that the warp and in particular the coating of size was by this time seven months old. Three further samples were woven in an attempt to take account of these differences: a reference sample was woven without the restrictor rods at one of the settings used during the second visit, and two fabrics were woven using lease rods at settings which duplicated those in use at ZhuZhou Mill.

Following analysis of the reediness exhibited by the fabrics, a further sample was woven at a different restrictor rod height.

3.2.4.3 Experimental procedure

An identical procedure to project 3 was used.

3.2.4.4 Results and discussion

The eight graphs in Appendix 15 show the effects of the various settings on static warp tension.

Results are shown in appendices 16 and 17. In order to facilitate comparisons a similar format has been used as for the results from project 3.

The first graph shows the effect of using the restrictor rods to halve the length of the rear shed. The restrictor rod setting of 15.4 cm was estimated to be that which would displace the upper and lower sheds by equal amounts so that the tension differential between them would not be affected. The tension in the upper shed position increased by a few cN whereas the tension in the lower shed remained approximately the same. This indicates the restrictor rods were perhaps 2 mm lower than the intended position, a difference of no importance to the investigation. The important aspects are that positioning the restrictor rods half way between the warp stop motion and the rear heald shaft did not increase warp tension by an unacceptable amount, and that the end tension at healds level was reduced to a very low level. This latter effect is due to the increased difference in warp length between open and closed shed positions which results from shortening the rear shed.

The second graph, which shows the effect of raising the restrictor rods to four different levels is very significant. Raising the restrictor rods causes a considerable tension difference between the upper and lower shed positions. It is precisely this difference in tension which causes the reduction in reediness. Restrictor rod heights of 12.8 and 13.4 mm produced the same effect i.e. the minimum warp tension in the upper shed position. Raising the restrictor rods beyond a setting of 13.4 serves only to increase tension in the lower shed position. The setting of 14.4 cm was the additional one woven after reediness had been judged. The fact that small differences in restrictor rod height have large effects on tension means that accurate settings become more critical if restrictor rods are fitted to a loom.

The third graph shows the effect of raising the backrest. If there was no gap between the rods, and the effect of friction was low, then raising the backrest would have had no effect, however, there must be a gap of at least 3 mm between the rods in order to permit the insertion of a reed hook, and the frictional effect was not known. In the event the third graph shows that the effect was negligible. This means that a constant backrest setting of 10cm can be used with the restrictor rods, thus avoiding the need to alter the mounting arrangements for the warp stop motion.

The fourth graph four shows the effect of moving the tension weight from position six to position 7. The tension in the upper shed position remained very low, but the tension in the lower shed position increased by approximately 1/4. This is approximately double the tension increase reported in section 3.1.4, which was recorded when weaving without restrictor rods. This result suggests that if the restrictor rod height is such that the warp tension in the upper shed position is already at a minimum all of the increased tension is borne by those ends in the upper shed position, i.e exactly half of the total ends. This accounts for the greater increase in tension and again points to the fact that the accuracy of loom settings when using rods is more critical.

Graph 5 shows the effect of delaying the healds level timing by 20°. Using a later heald timing reduces abrasion on the ends and reduces the tension acting on the ends at beat-up when weaving fabrics which require medium to high weft densities, but reediness and weaving over could increase. Since the weft density is such that the increase in warp tension at beat-up is small and abrasion of the ends by the shuttle does not cause problems in ramie weaving, the earlier healds level timing is preferable.

Graph 6 shows the effects of using lease rods to shorten the back shed. Samples 10 and 11 were woven using the extremes of lease rod position observed at ZhuZhou Mill. For sample 10 the second lease rod was just 1.5 cm closer to the rear heald than the position used for the restrictor rods. A comparison of the tension cycles is most revealing. The tension at healds level is reduced to a similarly low level when using restrictor rods or when using lease rods, but the increased tension difference between raised and lowered ends which was recorded when using restrictor rods did not occur when using lease rods, in spite of the back rail setting of 7.5 cm. In fact, apart from the low tension at healds level, the tension cycle is almost identical to that recorded for sample 1. Since sample 1 was woven with neither restrictor rods or lease rods and with a back rail setting of 7.5 cm, it can only be concluded that using lease rods largely negates the effect of raising the back rail. Positioning the second lease rod 8 cm further forward considerably increased the tension level in both upper and lower shed positions.

The final two graphs compare the static tension cycles when measured between the weaver's beam and the back rail and between the restrictor rods, or the second lease rod, and the rear heald shaft. The third curve in the seventh graph shows a repeat measurement of the tension in the same end as the first curve. The tension was measured again to see whether it decayed during the ten minutes or so which elapsed between the tension readings by an amount sufficient to render the results questionable. The tension cycles are similar in all cases. This means that measuring the static tension between the beam and the back rail can be used as an indication of the static tension in the shed. This does not mean that the tensions in the two positions will be the same when the loom is running - this will depend on many factors - but since a method which would allow measurement of end tension in the shed whilst the loom is running does not exist, the point is academic.

The first seven columns of the results table in Appendix 16 show the sample codes and loom settings used. The 12 samples woven during March 1994 are coded 1 to 12; samples O,S,L and M were woven during August 1993 and were used during the reediness comparisons; sample ZhuZhou 1 was the one of four fabrics supplied by ZhuZhou Mill during August 1993 which had least reediness.

The two columns which record the amount and position of clinging ends in appendix 6 are not shown in Appendix 15 since the results did not vary. When using restrictor rods some clinging occurred between 2 cm and 4 cm in front of the rods. When using lease rods any clinging tended to be approximately 2 cm in front of the rods. It was noted that a build up of fly occurred in both cases, but that it accumulated more rapidly when using lease rods.

Column eight shows the percentage relative humidity recorded as each sample was woven. The level on each day depended mainly on whether or not it was raining.

The next three columns show the occurrences of warp breaks by cause. All sample lengths were 150±5 cm except for sample 12 and those samples for which no warp breaks are recorded. In these cases the lengths were just sufficient to permit assessment of reediness. The high incidence for samples 1,2 and 3 can be attributed directly to the low relative humidity. In the case of sample 2 a patch of poor sizing was also indicated by the occurrence of several taped ends (taped ends are ends which are stuck together). Sample 12, for which the second lease rod was very close to the rear heald, recorded three breaks in spite of a sample length of only 25 cm. It was because it seemed likely that this high breakage rate would continue that weaving was stopped at this point. The variations in relative humidity mean that the results cannot be compared to those of the previous visit, or to those recorded at ZhuZhou Mill, but the fairly low number recorded once relative humidity increased is encouraging.

Columns 12 and 13 show that using either restrictor rods or lease rods to shorten the back shed largely eliminates the problem of cracks in the fabric. Yarn clinging which led to those minor cracks which did occur were usually the result of gross yarn faults.

Column 14 shows a fairly high incidence of weaving over, especially under conditions of low humidity. Most of the occurrences were in the same place in the fabric, and were traced to an incorrect temple setting and can be discounted.

Columns 15 and 16 show the results of comparing reediness for samples woven during March 1994, four samples woven during August 1993 and the best sample from ZhuZhou Mill. The main aim of project 5 was to produce reediness equal to the best sample woven during August 1993 (sample O) without incurring an excessive number of warp breaks. Samples 1,3,8 and 10 were excluding from the final judging since preliminary comparisons proved them to have equivalent reediness to other samples which were included. When considering these results it should be remembered that samples 2,L and M were woven using settings which were expected to result in reedy fabrics. Appendix 16 contains the samples.

Sample 11 was woven using lease rods and settings which duplicated those in use at ZhuZhou Mill, and this sample did in fact exhibit a similar degree of reediness to the best sample supplied by ZhuZhou Mill. There was considerably less reediness in all samples woven using restrictor rod settings of between 12.8 and 13.9, and all of these have an excellent appearance for ramie fabric having this construction.

A final sample, sample 12, was woven after the reediness results had been analysed in order to assess the effect of raising the restrictor rods by a further 5 mm. It exhibits reediness approximately equivalent to that which occurred using lease rods.

Appendix 17 contains an selection of the samples woven which illustrates the range of reedinesses obtained.

3.2.4.5 Preliminary Mill trial

The differences in conditions at the R.T.D.C and ZhuZhou Mill meant that it was essential to conduct a Mill trial using the restrictor rods before firm conclusions could be drawn as to their usefulness. Mill trials are lengthy undertakings, and, as there was clearly insufficient time for a full trial before the conclusion of the project, Mr. Ye was asked to devise and undertake a preliminary trial and fax the results before the end of May 1994 in order to permit their inclusion in this report. The results are shown in appendix 18. There are three main features: replacing the lease rods with restrictor rods led to a slight reduction in the warp breakage rate, largely as a result of the reduction in the accumulation of fly; fabric appearance was improved; and the weaver found the restrictor rods somewhat inconvenient. The 'inconvenience' factor may be discounted - it is more convenient to draw in through restrictor rods than the lease rods, however, it should be remembered that the weaver was accustomed to the latter.

The results of the preliminary trial confirm that the use of restrictor rods should lead to improvements in weaving efficiency and fabric appearance. The low material cost - less than 100 Yuan ($12) - and simple construction means that, although they are more expensive than lease rods, they are clearly affordable and could be manufactured in-house. Details of a proposed full trial are included in appendix 24.

3.2.4.6 Conclusions

The use of lease rods largely eliminates the problems caused by clinging ends, in particular the formation of cracks in the fabric. Provided that the second lease rod is not positioned too close to the rear heald shaft, the use of lease rods does not incur an excessive increase in warp tension. However, lease rods also partially negate the effect of raising the back rail thus precluding the possibility of minimum reediness. The accumulation of fly in front of the second lease rod is also cited as a cause of warp stoppages in the production studies conducted by ZhuZhou technologists.

Warp restrictor rods also prevent cracks without an excessive rise in warp tension, but they also cause less fly to accumulate, and, most importantly, allow reediness to be minimised to the extent that the aims of the project were exceeded.

Warp restrictor rods require quite precise settings, ± 2 mm would be adequate, but those settings are not difficult to achieve, particularly if a simple gauge is constructed for the purpose.

Warp restrictor rods cost more than lease rods but are are certainly affordable. The cost of the materials is less than 100 Yuan ($12), and the manufacture is straightforward.

It is considered that the application of restrictor rods to this and other ramie fabrics would yield considerable benefits, and the next step should be a trial under mill conditions. Details of a suitable trial are contained in appendix 24.

4. Sizing

4.1 Sizing Materials (Project 1)

An investigation was carried out at Bolton Institute with the collaboration of Allied Colloids Ltd. between July 1993 and February 1994 with the aim of finding improved sizing materials for ramie warps. Allied Colloids are a major UK manufacturer of chemicals and other products whose Textile Division are well established as suppliers of sizing materials. The time scale for the projects was as follows:

July 1993 Preliminary meeting between Vernon Heap and Adam Maliczewski of Allied Colloids Mr. Ye and the author to discuss the project and the contribution of Allied Colloids.

July 1993
Sept 1993 Allied Colloids investigate six potential size mixes and make recommendations.

Oct 1993 Mr. Ye sizes samples using the single-end sizing machine at Huddersfield University.

Oct 1993
Dec 1993 Mr. Ye conducts weaving trials and related tests at Bolton Institute School of Textile Studies.

Jan 1994 Mr. Ye prepares report entitled "Evaluation of Two Sizing Recipes for Ramie Yarns".

Feb 1994 Allied Colloids conduct sizing trials with yarns sized at ZhuZhou Mill.

Feb 1994 The author conducts weaving trials with yarns sized at ZhuZhou Mill.

Appendices 19, 20 and 21 contain the reports by Allied Colloids and Mr. Ye referred to above. This section summarises the main findings.

The project took place in three phases. During the first phase Allied Colloids duplicated the size mix in current use at ZhuZhou Mill, sized a sample and tested it on their 'Eurotech Abrader' laboratory abrasion tester. They then attempted to improve performance using 'Vicol'-based sizes. Samples of the two which gave the best performance and the duplicate PVA/CMC/corn starch size were supplied for the second phase.

Mr. Ye sized samples of ramie using the PVA/CMC/corn starch size and the most promising of the Vicol/corn starch sizes (difficulties in sizing and the low production rate of the single end sizing machine precluded use of the less promising size). He assessed the sized yarn in three ways: by weaving them on a Northrop shuttle loom; by examining the appearance of the yarn when it was a short distance from the fell; and by measuring the tensile properties of the sized yarn both before and after weaving.

Although the PVA/CMC/corn starch duplicated the ingredients used in ZhuZhou Mill, there was no guarantee that the quality of the ingredients was the same, and it was certain that the processing conditions were different. Ideally, the third phase would have consisted of sizing and testing yarn using size ingredients obtained from ZhuZhou Mill. However, this could not be arranged, indeed it was not until Mr. Ye returned to ChangSha that it was possible to obtain yarn sized at ZhuZhou. This yarn was tested by Allied Colloids and the author.

The Eurotech Abrader used by Allied Colloids is a severe test of abrasion resistance. It showed the better Vicol/corn starch mix to perform slightly better than the duplicated PVA/ CMC/corn starch mix, and showed the yarn sized at ZhuZhou Mill to perform equally as well. The weaving trials conducted by Mr. Ye are a more complex test in that, as well as abrasion, they involve cyclic stressing and allow the clarity of shed formation to be assessed. His report indicates that the clarity of shed formation was better for the yarn sized using the Vicol/corn starch mix than that sized using the duplicate PVA/ CMC/corn starch mix. In addition, the tensile tests showed a greater number of samples after weaving which had very low tensile strengths and/or elongation at break. Time precluded tensile testing of the yarn sized at

ZhuZhou Mill, but the weaving performance was markedly worse with respect to both end breakage rates and clarity of shed formation. This suggests that the Vicol containing sizes are likely to perform better than the current size mix, but also that control of the sizing process may be a factor in the lower performance of the yarn sized at ZhuZhou Mill. It is considered essential that further investigations be conducted, and suggestions are contained in appendix 24.

4.2 Process Control In Sizing (Project 2)

Improving process control in sizing is a long term project for any weaving mill, and as such its conclusion lies beyond the term of this U.N.I. D. O. project. It has been possible to establish by observation that there is room for improvement, for example: creel braking arrangements were irregular, some brakes being in a state of disrepair; the stretch applied was high; and the moisture measuring transducers were not working properly. Appendix 24 and Research Report 3 give further experimentation and control procedures which should be adopted in order to optimise process control in sizing.

5. Other Yarn Preparation Processes (Project 9)

5.1 Winding

During the author's first visit to ZhuZhou Mill several problems became apparent, in particular misshaped cones, considerable variations in winding tensions, bouncing cones and the failure to remove gross faults. It was decided that Mr. Ye would concentrate on winding and warping during the two or three weeks between his return to ChangSha and the author's return. This work was facilitated by the purchase of and supply to the R.T.D.C. of a Schmidt electronic single-end tension meter by The University of Leeds Innovations Service.

Mr. Ye observed considerable improvements in the winding process in that there were far fewer soft, misshapen packages and no incidence of cones bouncing. End tensions were also more regular - the data is included in appendix 22 - particularly when the incorrect number of weights applied to three spindles were spotted and corrected.

A second experiment, designed to indicate the efficacy of the clearer settings was very revealing. The Uster regularity tester at the R.T.D.C. was used to the measure the regularity of the yarn from a number of ring tubes and cones removed from the winding frame. The aim of clearing is to remove faults, especially thick places, which would either cause stoppages in further processing or mar the appearance of the woven fabric. As a result the coefficient of variation of the yarn on cone should be lower than that on ring tube. Mr. Ye's measurements showed no improvement, in fact, the coefficient of variation of the yarn on cone was slightly higher. This would tend to indicate that the clearers were not at the optimum setting. The second part of this experiment was to have been to adjust the clearer setting and repeat the regularity testing, however, staff at ZhuZhou Mill preferred not to do this because "...all fifty heads would need to be adjusted". This point is discussed further in appendix 24 and Research Report 3.

Three further investigations into winding were carried out during the author's final visit. The first took the form of a general inspection of each spindle during which it was found that the winding frame was indeed in a better state of maintenance than during the first visit. Even so, three heads had either the wrong number or the the wrong type of tension disc; two were bouncing continuously; three failed to automatically lift off the driving drum when full; and several had stop motion arms which had become grooved to such an extent that the yarn traverse was restricted leading to faulty package build.

The second investigation took the form of a production study. Mr. Ye, Miss Zao and the author each observed six spindles for one hour, i.e. a total of eighteen spindle hours, and recorded the number of ring tubes creeled and the number of stoppages. The results, together with the results of three routine production studies conducted by Miss Zao, are included in appendix 22. The results of the studies were similar: the breakage rates were between 0.16 and 0.35 per ring tube, and the most common causes were fly accumulation, thick places and trash.

The final study compared the sizes and masses of randomly selected cones. The aim of this was to check for indications of variations in package density. The masses and dimensions of ten centres were also checked. The results, which are also contained in appendix 22, suggest that there are variations both in package density and the length of yarn contained on cones.

The implications of these findings have serious effects on warping, sizing and weaving efficiency, fabric quality, and, ultimately, profitability. These points are discussed further in appendices 24 and 27.

5.2 Warping

Prior to the author's third visit, Mr. Ye measured the running tension of each end being warped on one of the older, drum driven warpers which was processing 36's Nm ramie. This test was to have been conducted on the newer, spindle driven warper, but by this time this machine was no longer being used, since the Mill staff have concluded that its processing speed is too high for ramie yarn. It is understood that there are plans to use it for yarns which are composed of other fibres. The results, which are summarised in appendix 23, show that the variations in tension are quite small, in fact, apart from one or two positions, they are as even as could be expected from such a basic creel.

Mr.. Ye and the author also conducted a production study for one hour, the results of which are contained in appendix 23. The majority of the fifteen stoppages can be attributed to faults which were either not removed, or were introduced, during winding. Appendix 23 also contains the results of six production studies conducted by ZhuZhou staff. Recommendations are made in Research Report 3.

5.3 Enzymatic Treatment of Warp Yarn (Project 11)

This was described in the author's first report as "...the most tentative proposal". The hypothesis was that if the surface hair could be either weakened or removed by the action of enzymes problems related to shed formation would be lessened. Early results from Dr. Burkinshaw and Mr. He's experiments indicated that the severe loss in tensile properties would far outweigh any potential benefit from a reduction in hairiness. Consequently, this project was not pursued.

6. Conclusions

1. Given the existing standards of warp preparation it is not possible to weave good quality plain weave ramie fabric from fine yarns without the aid of additional attachments.

2. The lease rods which are currently used in ZhuZhou Mill are effective in reducing the incidence of cracks in the fabric but are imprecise in their action, do not permit minimal reediness, encourage the build up of fly and increase warp tension.

3. Experimental work and an initial Mill trial have shown that restrictor rods also increase warp tension but overcome the other limitations of lease rods. It is strongly recommended that a full trial commence as soon as possible.

4. Restrictor rods may also be applied to the Chinese-made rapier looms, should they eventually be used to weave ramie fabrics.

5. There are many examples of good practice in the weaving shed at ZhuZhou Mill, however, there are a number of suggestions contained in Research Report 3 which should bring about improvements in efficiency and fabric quality.

6. This U.N.I.D. O.project has established that the highest standards of yarn preparation are essential to efficient weaving of high quality ramie fabric.

7. There are also many examples of good practice in the yarn preparation departments at ZhuZhou Mill, but again, a number of improvements are suggested in Research Report 3.

8. It is likely that Vicol containing sizes would give improved weaving, but a trial should not begin until process control in sizing has been optimised.

9. It seems unlikely that the advantages of modern rapier looms can be realised in ramie weaving, however, Chinese-made rapier looms are likely to be viable, provided that yarn preparation is first optimised.

10. The apparent reluctance of operatives at ZhuZhou Mill to wear hearing protection is exposing them to the likelihood of hearing loss in the long term. This situation should be remedied without delay.

11. Mr. Ye has shown himself to be a capable and enthusiastic weaving technologist, well able to diagnose problems and develop strategies for their solution. The R.T.D.C. also has two further very competent weaving technologists in Mr. Xie and Mr. Bing.

12. This U.N.I.D.O. project has made much progress in a relatively short time in identifying problems and investigating possible solutions. As with any research, not all of the questions have been answered and new questions have arisen. The author is confident that the technologists have the ability and enthusiasm needed to provide the answers.

7. Acknowledgement

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Steve McMahon
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