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Ironmaking by the bloomery process at Nornäs, Sweden, in 1851

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Editorial Note

This description was published as an appendix to the book by Severin Solders, "Alvadens Sockens Historia, Pt. III. Myrjärn - Hemsmide - Liebruk", which was published in Stockholm in 1946. It was thought worth translating into English because of the current interest in the mechanism of the bloomery process and its detailed step-by-step treatment. The process may be compared with that described by Ole Evenstad for Norway and published in Bull. Hist. Met. Group, 1968, 2, (2), 61-65.

We are grateful to Dr Inga Serning for supplying the original and for arranging to have the original Swedish units converted into their modern equivalents. We have to thank J.P. Tylecote and Mrs Hedberg for the translation.

IRON-MAKING IN NORNÄS, 1851

(From the College of Mines archives, letters, and papers, supplementary series 1830-1857)

Minutes

Concerning measurements taken, and concerning other noteworthy things at Fänjåsblästan, situated in the parish of Särna, next to the border with Elfdalen and Nornäs village, as well as about the iron-smelting which took place there on 6th August 1851 and, further, about the forging at a bar-iron hearth near Avesta, of the blooms obtained from the 3rd smelt and also about the forging of them, and about the testing of the resulting iron bars at the manufacturing forge at the last named place on the 21st of the above-mentioned month and year.[1]

PART 1

The upper part of the furnace, or the "pipe", had almost the shape of a distorted and inverted cone 12 inches[2] in height and 1 fathom top diameter; but its lower part or the stand itself was built in one piece with the upper part, in a parallelepiped shape 20 inches long (between the tuyere-wall and the blowing-wall), 18 inches wide and 18 inches deep. The small departures from a conical shape were of course at the transition from the stand's rectangular shape to the round shape of the pipe. The stand was made of granular limestone. It did not have a slag tapping hole.

The tuyere was circular and of forged iron; its inside diameter, at the opening, was 7/8 inch; its taper to the bottom ¼ inch over its whole length, which was 12 inches; the height of the inner lower edge above the bottom, 4½ inches; the projection (in the stand) in front of the tuyere-wall, 2½ inches; but originally, before the tuyere was burnt off, this dimension had been 3½ inches.

The bellows consisted of two wooden boxes in parallelepiped shape about 3 square feet in cross-sectional area and an 18 inch high remainder, which for the time being, owing to the shortness of the lifting pole, was not more than 11 inches. Driving power came from a 5 foot breast-waterwheel, to the shaft of which two cords were fastened. Most of the water was brought in from two springs, the water of which was so warm that even in the most severe winter it almost never freezes at the dam. The tools were : spit, hook, fire pan, shovel, wooden rake, and tongs.

PART 2

Time Hrs Min	**The first smelt. Smelter : Hård Lars Ersson in Nornäs**
A.M. 10 45	The furnace was filled with rather dry, knotless seasoned wood, cut in 1 to 2 decimal square inches cross-sectional area. The wood was set up in the bottom of the furnace, in a cone shape with the point downwards, but, from the middle of the furnace, it was put in horizontal layers, and that continued up to a height of 2 to 3 spans on top of the upper edge of the furnace. The wood was lit at the bottom without blast.
11 00	The flame was visible on top.
07	Started to lay a little ring of charcoal round the edges and continued with that for 5 minutes, according to how the charring of the wood was progressing. The total addition of charcoal amounted to just about half a barrel.
23	First, thin layer of ore[3] added round the edges, after which the charcoal was thereby compressed and the wood inside lifted somewhat so that the charring was speeded up. Further, a about 3 minute intervals, more ore was placed on the top of the charcoal pile, as the wood up there became more and more charred.
30	Began gentle blowing, as almost all the wood on top was charred, even if some in the middle was to some extent still uncharred.
42	Blast increased.
45	Charring of the wood inside was now also completely satisfactory. Just about half a shovel, approximately 1/6 of a peck, of ore was put over the hole pile whenever the coals were getting bare, or the ore had sunk between them, and that was about every 3rd minute. Between every addition the charcoal was packed down with a wooden rake.
50	An air vent hole was pierced through the middle of the charcoal pile.
55	Blast further increased.

11 58 Middle hole pierced again.

P.M.

12 01 The last shovel of ore was put on, and now the total ore addition consisted of one pail 10.7 decimal inches diameter and 9.5 decimal inches deep, of a better sort, and one shovel, of just about half a peck, of a worse sort. Before the beginning of blowing both sorts were carefully cleansed of stone, well mixed and intimately blended with each other.

09 The blast was increased again. Compressing of the charcoal continued frequently, although no more ore was being added. When the hole in the middle became too big, and when the blast tried to escape more on one side than the other, charcoal was scraped out from one place to another, as required.

20 A handful of stove ash was taken, of which 1/6th or 1/8th was put in the middle of the pile "to encourage the smelting".

42 Three pinches of ash were put on for the last time, and with that about half of the original quantity had been used. The adding of these ashes had been carried out approximately every 5 minutes.

45 The charcoal surface had become level with the upper edge of the rectangular portion; and when adding the charcoal it could be seen how the pieces were somewhat stuck to each other by the melting ore.

58 Small charcoal was scraped away from above the tuyere down to its level and a large firm piece placed there instead, to encourage the deflection of the blast towards the opposite wall.

1 00 Sparks of burning iron began to be thrown up by the blast, and this then increased more and more.

03 The ore from both walls to the sides of the blast stream was pushed back towards it, and this operation was afterwards repeated every second or third minute.

05 Two double handfuls of charcoal were put on above the tuyere.

11 A few pinches of ash were put on again.

16 A double handful of charcoal was put on. The slag was now seen to be flowing quickly with white grains of iron in it.

19 The blast was slowed down and it was

20 turned off. The finished bloom was picked up and hammered all round, and found to weigh 17 pounds victual weight,[4] to be soft and to have only a thin layer of slag around it. The slag was picked up afterwards as well as small pieces which contained iron, ore and slag, caused by the cold walls.

The second smelt. Smelter : Hård Lars Ersson in Nornås

1 30 The furnace was filled with wood of the type previously mentioned; and the flame was now visible almost immediately.

1 45 The ring of charcoal was put on. The ore was blended from one pailful and one shovelful of better ore and one shovelful of poorer ore. (The pail contained 5 shovelsful.)

2 00 The first ore was put on. Subsecuent additions, as well as the charcoal packing, now proceeded as previously described.

12 The blast was started and

25 then increased, just as all the wood became charred. The first ore addition was the largest (about one whole shovelful) in order to extinguish the large wide ring of coals, so that they should not burn up to no purpose. Later, as the pile of coals got smaller, the ore additions were then also reduced down to 1/3rd or 1/4th of a shovelful.

43 Finished adding ore and simultaneously increased the blast. Ashes were now added, as during the first blowing, in small portions, but this time more, or almost two handfuls, were used. When the blowing was half completed, the pile of coals was kept highest above the tuyere, "to secure a stronger heat towards the opposite wall."

3 50 After scraping off, the large coal was placed above the tuyere.

59 The iron sparks started to burn, and then, as during the first smelt, a double handful of coals was put on above the tuyere.

4 05 Again the same amount of charcoal was added above the tuyere "to encourage the heat towards the opposite wall."

08 Blast stopped, because the machine broke down, but it was started again. Meanwhile, the slag had flowed into the tuyere, so that

23 the blowing had to be stopped completely and the bloom taken out. In spite of considerable loss of iron on this occasion, the bloom registered 18 pounds victual weight. While it was still red it was hacked into two pieces with an axe, in 4 minutes.

The third smelt. Smelter : Hård Lars Ersson in Nornås

5 15 The furnace was filled with wood. The ore was blended in the same way as at the 2nd smelt. When all the wood had become black or charred at the surface and just when the flame over the whole furnace was largest,

25 the usual measure of charcoal was put on around the edges, "so that the charcoal would be glowing well by the time part of the wood becomes completely charred." Later when the charcoal was fully aglow, and empty spaces started to show round the edge, the coals were broken and the wood, with some interruptions, lifted up, so as to give better air for its combustion. Afterwards the coals were packed carefully against

40 the outer edge again, and the first ore addition was made. The additions and packing-downs then continued as usual, until the white flame emerged from no more than 1/4th of the surface of the pile, and that just from the very top part.

6 00 When the combustion was sufficiently advanced, the blast was turned on. The machine's wheel shaft made only 7 revolutions per minute to begin with; but, when all the sticks were

10 charred, the blast was increased to 8 revolutions per minute of the wheel and after that it was increased every 5 minutes, until the wheel,

20 as ore addition was complete, reached a speed of 10 revolutions per minute and finally,

25 at the last increase of blast, a speed of 11 revolutions per minute. After completing the ore addition the ash additions were started, and the scrapping together, in a similar way to what took place during the 2nd smelt. This time a hole appeared by itself through the middle of the pile, so no piercing was required.

7 25 Raking off above the tuyere took place and the larger coals were put there.

30 New coal was put on.

45 Two double handfuls of coals were put on, to cover the broken pieces of ore from the sides, that were melting.

50 Again a large coal was placed above the tuyere.

8 00 The bloom was hacked into two parts, weighing together 23 pounds victual weight. This bloom was bought for the account of the Royal College of Mines, and later forged to bar-iron, which is now kept in the Royal College of Mines Mineral Cabinet.

The fourth smelt. Smelter : The prospector and blast furnace foreman P. Petterssen

8 20 Started to fill the furnace with wood. With regard to quality, quantity, and blending, the ore was the same as that used for the 3rd smelt, and the quantity of charcoal was also just the same as it was during the previous smelts.

35 The charcoal was put on.

50 The first ore addition was made.

9 00 Started the blast, which began to be increased after 10 minutes, with further increase every 5 minutes after that.

15 The flame stopped.

35 The last ore addition was made, and at the same time the blast was increased for the last time. The speed of the bellows wheel then reached the same maximum as before, 11 revolutions per minute.

10 40 Pierced the hole in the middle; then, for the first time, some pinches of ashes were put on, and this was repeated every 3-5 minutes. The packings down were carried out carefully. Once again charcoal was added at the end, in the same way and with the same amount as during the 3rd smelt.

50 The bloom was taken out and hacked in two. Its weight was 25 pounds victual weight. It was bought for the account of the Royal College of Mines and is now kept in its Mineral Cabinet.

Remarks

1. A suitable ore blend is needed so as to prevent too much iron from getting into the slag; this had been, according to Hard Lars Ersson, the most difficult thing to discover.

2. The reason why twigs and heartwood must not be used in the bloomery furnace was that "that kind of wood burns too long with a white flame and the coals finally created from it get too hard; the other type of coal produces the right effect simultaneously."

3. The parallelepiped shaped charcoal measure at Fänjäsblästan, the dimensions of which were 1.51ft x 1.27ft x 1.46ft, contained 2.766 cubic feet[5] or 27⅔ cans. Now, if the two handfuls of charcoal added towards the end of the smelt are counted too then one finds that the charcoal consumption was just about 28 cans or ½ barrel, for each smelt.

4. The wood was sawn, with special waterwheel power, into log-ends 3, 4, 5, and 6 spans long, so that the lengths would suit the different dimensions of the furnace. A log of 7 to 8 inches diameter and 7 to 8 cubits length was used up at each 3 hour blowing.

5. The work with the bloomery furnace can be handled by a smelter and one assistant, the latter's most important work being to cut wood, but if the smelting, as planned, is to continue night and day, there must be at least two smelters, who replace each other after each completing their shift of three smelts. The assistant, on the other hand who, during each blowing, should have the chance to sleep at least half the time, might possibly be able, alone, to serve both the smelters.

6. In order to get a comparison between the quantity of iron produced from the ore in a bloomery furnace and in a blast furnace, the following details may be useful :

According to information from the prospector and blast-furnace foreman P. Pettersson, at the blast furnace at Paulistrőm, in the Kalmar region, it was normal to put on 1100 pounds rock weight[6] of lake and marsh ore at each addition and, as well as this, 20 charcoal additions of 9 barrels each, every 24 hours, from which about 9½ ships pounds pig-iron[7] weight of iron was obtained.

Therefore, 22,000 pounds rock weight of ore produced about 4860 pounds rock weight of iron. But, as a heaped half-peck of clean-washed ore was found to weigh 14 pounds victual weight, it follows that a barrel would weigh 14 x 32 = 448 pounds victual weight, or 448 x (2500/2210) = 507 pounds rock weight; so that 22,000/507 or 34.5 barrels of ore produce 4860 pounds rock weight of pig iron.

By comparison, the ore smelted at Fänjäsblästan, comprising 1 1/5 pails of better grade and 1/5 pail of poorer grade, gave 25 pounds victual weight or (5.250/4.221) x 20 = 28 pounds rock weight of workable iron. Now the diameter of the pail was 1.07 feet and its depth 0.95 feet, so its volume was 0.885 cubic feet, and if the amounts are now added, then the quantity of better-grade ore becomes 0.855 x 1 1/5 = 1.026 cubic feet, and of the poorer grade = 0.171 cubic feet, and the total quantity of ore = 1.197, or almost 1.2

cubic feet, which is 12 cans or 12/56 = 0.214 barrels. So now we have 0.214 barrels of roasted ore giving 28 pounds rock weight of bloom, so that, from the relationship 0.214/28 is as 1/x, one finds that 1 barrel of blended ore, cleansed by roasting, gives 28/0.214 = 130 pounds rock weight of bloom. The comparison between the results at the Paulistrõm blast furnace and the Fänjäsblastan bloomery furnace therefore becomes as follows :

1 barrel of lake and marsh ore, cleansed by washing, produced at Paulistrõm, 112 pounds rock weight of pig-iron

1 barrel of blended marsh ore, cleansed by roasting, produced at Fänjäsblästan, 130 pounds rock weight of bloom.

PART 3

Both the blooms produced at the 3rd smelt, which, according to the weights inspector in Nornäs, together weighed 23 pounds victual weight, weighed no more than 21 pounds victual weight on arrival at Avesta. Wear and tear due to the severe shaking on the post-chaise during the 30 league journey, together with some possible differences in the scales, even if both were crowned, could perhaps have caused this difference in weight.

The forging of the large piece, which weighed 11 pounds, in the bar-iron hearth, by a smith who was not used to that type of iron, was taken much too hard (white heat instead of light red, as urged by Mines Inspector Öngren) with the result that this piece broke into three at the first blow under the bar-iron hammer. However, the bits were gathered up, carefully beaten together, and then again several times with great care, which finally resulted in an iron bar of 7½ pounds which, hardened, with grey-blue stripes on the surface, showed a steel-like nature.

The bar withstood many blows on the edge before it broke and the fracture was seen to be mostly crystalline but also, to a small extent, at one edge, somewhat stringy.

From this bar some horseshoe nails were then forged, which were so soft that, in spite of the fact that the point was bent cold about 20 times to and fro, it still did not break off, but only split near the tip, as a result of the previously mentioned unevenness of the iron.

The smaller bloom of about 10 pounds was not heated so hard as the larger one; it was also turned more often in front of the blast. The consequence was that this bloom did not break under the hammer, and it produced a bar of exactly the same weight - 7½ pounds victual weight - as that from the larger bloom.

The quality of the iron was equal in both bars.

Even if the loss from the latter bloom was a whole pound less than from the former, it might, with a smith who was used to such iron, have been even less, and then if one also remembers what dropped into the hearth, one can see that longer experience with the same materials and, finally, with the larger blooms of the future, would have provided an important replacement for the loss in weight suffered, so that one finds that the loss in this particular case was not of any special significance.

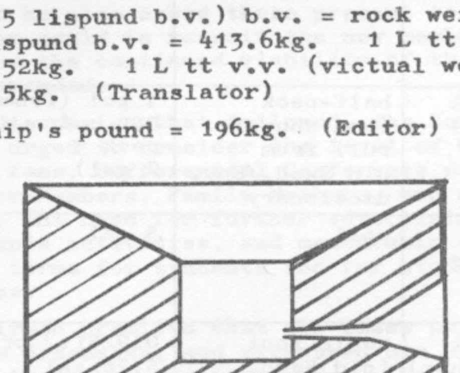
The reason that Hård Lars Ersson and Fider Lars Ersson in Nornäs again took up iron manufacture was that Langö Mill had started again in the 1840s and they were keen on having bog iron for their scythe manufacture. The method had been described to them by their fathers. At Langö they had made attempts to smelt bog ore in a bar-iron hearth but failed completely. Both these Nornäs men then got the necessary iron equipment from the mill, which also promised to buy all that they could produce at a price of 8 Riksdollar banco per ship's pound victual weight (170 kg), delivered at the mill (6 leagues away from Nornäs). In addition to this, they were able to sell to Horrmunds Mill, which lay considerably nearer and was owned by Varg Hans Ersson in Lövnäs.

How long Fänjäs bloomery was in use is not known. Probably the work was stopped fairly soon. Nevertheless, bog ore smelting was taken up again at the same place on one further occasion, namely by Fider Anders Pettersson, in the 1870s.

(Compare an article by H. Carlborg in Blad för bergshanterings vänner (Paper for Friends of ironworking), No. 17, 1922, 99 et seq.)

Notes and References

1. These minutes cannot, of course, include other than what I saw with my own eyes. If questions arise concerning a description of bloomery furnaces in general, with the relevant ores and working methods etc., then the best sources of information on these subjects can be obtained partly from Jernkontorets Annaler, XXIX, Volume 1, and partly from "A Short Description of Methods for Smelting Lake and Marsh Ore in Bloomery Furnaces", printed by Johan A. Carlbohm, Stockholm, 1794.
2. Here the word "inch" always means working inch (24.742mm) when the word decimal is not mentioned. The decimal inch = 29.69 mm. (Translator)
3. The ore, taken from Björnadalen and from Nornäs, was cold-roasted without having been cleansed of earth, sand and tree-roots by previous washing. The cold roasting procedure was said to have been carried out by placing alternate layers of wood and ore.
4. Victual weight (v.v.) = 17 scale pounds = 7.225kg. 1 tt v.v. = 0.425kg. 1 tt rock weight (b.v.) = 0.376kg. (Translator)
5. The arithmetic is wrong; it should be 2.8 cubic feet. (Translator)
6. (55 lispund b.v.) b.v. = rock weight = 55 lispund b.v. = 413.6kg. 1 L tt b.v. = 7.52kg. 1 L tt v.v. (victual weight) = 8.5kg. (Translator)
7. Ship's pound = 196kg. (Editor)



Section through Swedish bloomery hearth
Top part circular, bottom part rectangular

NOTES ON LENGTH, VOLUME, AND WEIGHT DIMENSIONS

Swedish Text	Literal Translation	Current English Equivalent	Current Metric Equivalent	Comparison with Hand-written Swedish notes on Original Text	Other Remarks
tum werktum	inch	0.973in	24.74mm	Page III says = 1/12 fot = 24.74 mm	Checked as correct by visit to library. Old Swedish inches and feet definitely shorter than English one
dec. tum	decimal inch (1/10 old Swedish foot)	1.168in	29.69mm	Page III says = 29.69 mm	
qvarter (6 werktum)	span (from old Swed./Eng. dictionary)	5.84in	148.5mm	Page IV says 2 to 3 qvarter = 0.3 to 0.5 m, i.e. qvarter = 150mm	OED gives span as 9in but visit to library confirms "kvarter" = 6 old Swedish inches
fot (12 werk-tum or 10 dec. tum)	foot	11.68in	296.9mm	Page III says 10 dec. tum = 296.9mm	Checked as correct at library
aln (4 qvarter or 2 fot)	cubit (from old Swed./Eng. dictionary)	23.36in	594mm	Page VIII says 7 to 8 alnar = 4 to 5 m, i.e. aln = between 570 and 625 mm	OED gives cubit as 18in but library confirms aln = 2 old Swed. feet or 24 old Swed. inches
famn (6 fot or 3 alnar)	fathom (from old Swed./Eng. dictionary)	5ft 10in	1782mm	Page III gives this as 1.8m	Fathom is 6ft but library confirms famn = 3 aln, i.e. 6 old Swed. feet
mil (18,000 alnar)	league (from old Swed./Eng. dictionary)	6.64 mils	10.689km	Page IX gives 3 mil = 320 km, i.e. 1 mil = 10.66km Page X gives 6 mil = 65km (i.e. mil = 10.84km)	OED says league is "about 3 miles" (5 km) but modern Swed. mil = 10km, and library confirms old Swedish mil = 36,000 old Swed. feet, i.e. 10,689 m
njupor	pinch				
näfve	handful	¾ pint	0.43 litres		Page VII (Remark 3) indicates 2 handfuls = ⅓ can, i.e. handful = 1/6 can = ¾ pint
kann	can	4.57 pints	2.60 litres	Page VIII says 27¾ kannor = 72.4 litres and 28 kannor = 73.3 litres. Page IX says 12 kannor = 31.37 litres, i.e. 1 kann = 2.62 litres	Page VIII of the text says 28 kannor = ½ tunna and Page IX says 56 kannor = 1 tunna. Library confirms kann = 2.60 litres and 7 kannor = 4 kappe (see below)
kappe (& skofvel)	half-peck (and shovel-ful) from old Swed./Eng. dictionary	1 gal (from OED : 1 peck = 2 gal)	4.55 litres	Page IV says ⅓ kappe = about 1.5 litres & "just about 1 kappe" = 4.5 litres	Confirmed at visit to library, which also showed that 4 kappe = 7 kannor
ämbare (5 kappe)	pail	5 gal	22.7 litres	Page IV gives calculated 22.5 litres from dimensions of pail in text	Page V confirms in text by saying 1 ämbare holds 5 skofvel (i.e. kappe)
kub. fot (10 kannor)	cubic-foot (old Swed. foot)	0.925ft^3 or 5.76 gal	36.0 litres	Page IX gives 0.855 kub.fot = 22.4 litres, i.e. 1 kub.fot = 26.2 litres	Based on old Swed. foot (see above). Library confirms & says = 10 kannor
tunna (32 kappe or 56 kannor)	barrel	32 gal	145.47 litres	Page IV says "just about ½ barrel" = 70 litres. Page IX says 1 tunna = 150 litres	Page IX confirms in text by saying 56 kannor = 1 tunna, i.e. 145.47 litres. Also confirmed at library

Swedish Text	Literal Translation	Current English Equivalent	Current Metric Equivalent	Comparison with Hand-written Swedish Notes of Original Text	Other Remarks
tt pund skalpund	pound "bowl" pound scale pound				
L lispund	20 pounds				
tt v.v. pund viktual-itevikt	pounds victual weight	0.936lb	0.425kg		Stated in printed footnote, Page V
L tt v.v. lispund viktual-itevikt	20 pounds victual weight	18.72lb	8.5kg		Stated in printed footnote, Page VIII
tt b.v. pund bergs-vikt	pounds rock weight	0.78lb	0.376kg		Stated in printed footnote, Page V
L tt b.v. lispund bergsvikt	20 pounds rock weight	16.58lb	7.52kg		Stated in printed footnote, Page VIII
Sk tt tack-jernsvikt Skeppund tackjerns vikt (26 lispund bergsvikt)	Ship's pound, pig-iron weight	428.8lb	194.5kg (according to library but 26 x 7.52 = 195.6kg)	Page IX says 9½ ship's pounds pig-iron weight = 1860kg	Text (Pages VIII/IX) says 9½ ship's pounds pig-iron weight is equivalent to 243 lispund rock weight, i.e. about right

Extraordinary General Meeting, 25 September 1971

Minutes of an Extraordinary General Meeting held on the occasion of the Annual Conference at Devonshire Hall, University of Leeds, at 7.45 p.m. on Saturday, 25 September 1971.

Apologies for absence were received from Messrs J. Angus and J.W. Butler and from Professor H. O'Neill.

Minutes of the A.G.M. 1971 having been published in the Bulletin, Vol. 5, No. 2, p. 79, these were taken as read and signed as a correct record, apart from an error in line 7, which should read "Bulletin, Vol. 4, No. 2."

There were no **matters arising**.

The Chairman explained that the meeting had been called to discuss problems that had arisen during the summer. The Iron and Steel Institute had informed the Group that it had been forced as an economy measure to withdraw all financial support from the Bulletin, amounting to about £700 per annum. Thus the Group now needed to be self-sufficient, and its present level of income put the frequency and format of the Bulletin at risk.

He assured the meeting that the Committee were making every effort to economize on the costs of administration, and to find ways of producing the Bulletin more cheaply, but it seemed unlikely that more than one issue of a simplified version would be feasible in 1972. He gave notice that, evem on this basis, an increase in subscription to £1.50 might well be necessary in 1973 but that the situation would be reviewed finally at the time of the 1972 A.G.M.

He proposed, and the Treasurer seconded, a motion that a category of Family Membership, at £1.50, should be instituted for 1972. This was passed without dissent.

The Treasurer drew Members' attention to the regrettably large number of subscriptions that were overdue, currently totalling about 100, and he also asked those present to do what they could to recruit the new members upon whom the continued viability of the Group depended.

In the discussion that followed, the Committee was urged to consider the level of Conference fees, differential Conference payments for Members, Family Members, and non-Members, the need for further advertising of the Group's activities, and membership on special terms for students and for student societies.

The Chairman promised that all these points would be discussed, and expressed his appreciation that they had been made. He asked that anyone with further ideas for ensuring the continued existence of the Group on a more sound footing should communicate with the Secretary.

There being no further business, this Extraordinary General Meeting was declared closed at 8.25 p.m.