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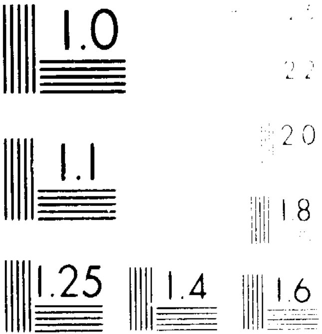
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org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China. PROJECT FOR THE MANUFACTURE OF ALUMINIUM DOORS AND WINDOWS IN GUANGZHOU, PEOPLE'S REPUBLIC OF CHINA

WINDOW AND DOOR DESIGN AND FACTORY LAYOUT

Report by W G Fancourt - expert in the design
and manufacture of aluminium windows

for the

United Nations Industrial Development Organization
Vienna

CONTENTS PAGE NO.

1. INTRODUCTION

This report describes the results of work done on mission DP/CPR/80/045/11-02 (Window Design) and the first part of split mission 11-03 (Plant Layout).

The expert left the UK on 13 April 1982 and arrived in Guangzhou on 22 April after briefings in Vienna and Beijing.

The work was done at the Guangzhou Steel and Aluminium Door and Window Factory and was completed on 21 June 1982.

The work on window design was completed for both the sliding window, as specified in the job description, and for the casement window.

The work on the first part of the plant layout, that is plant layout drawings showing equipment and workflow, and the listing of tools and equipment was completed as specified in the job description.

The first part of this report gives details of the main technical aspects considered in recommending modifications to the original window designs produced by the Counterparts.

The second part of this report gives details of the main considerations used for the design of the layout of the factory and the selection of the necessary equipment.

The full technical details of the design of the products and the factory and the many supporting calculations are not reproduced in this report.

2. PREVIOUS MISSION

This is the second report for the project. The first report headed PREPARATORY ASSISTANCE by Mr. A.W. Brace in May 1981 gives the background information relating to the project.

The two main changes in the situation between this report and the first report are as follows.

The proposed level of production specified in the first report is 12,000 m^2 of products per annum by 1985. The factory has now been designed in detail for a production of 635 m^2 per day on a single shift.

At the time of the preparation of the first report considerable problems were reported as a result of inadequate quality of extrusions. It now appears that these problems have been resolved to a large extent. Extrusions may still not be perfect but they are not the cause of problems to the extent described in the first report.

3. BACKGROUND INFORMATION FOR PRODUCT DESIGN

This chapter deals with the information of a general nature needed as background for the successful design of aluminium windows and doors.

The expert's opinion is that the various standards and specifications do not vary greatly in principle between the UK, USA and Western Europe.

The various 'western' standards differ in detail and reflect national preferences. For the purpose of the mission it is considered appropriate and convenient to compare such standards as are available in the People's Republic of China with British Standards. British Standards have the status of recommendations which most manufacturers follow. They are not the law.

The Counterparts are free to make such further comparisons of the detailed differences between the various western standards as they consider to be appropriate. The proposed visits to the Aluminium Window Associations in London and New York on the Study Tour will assist in this respect.

The expert's opinion is that the examination of the differences between western standards will not contribute directly to the improvement of the performance, appearance, quality or ease of manufacture of the Counterparts' products but may assist in the formulation of National Standards for the People's Republic of China in the areas where none exist at present.

The following sections of this chapter deal with specific items of background information. The various British Standards and Codes of Practice mentioned in these sections are the latest publications. For example, British Standard Code of Practice CP153:Part 1:1969 is not an obsolete standard but that which is currently applicable and was last revised in 1969. Photocopies of all technical publications mentioned in this report have been supplied by the expert to the Counterparts, except where stated otherwise.

A. Wind Loading

The first and most important consideration for the design of aluminium windows and doors is their ability to withstand the maximum wind loading which may be imposed upon them. In the change from steel windows to aluminium windows it must be recognised that aluminium is a weaker material than steel and aluminium window sections are thinner than steel window sections. These two factors combine to produce aluminium windows which are much weaker than the equivalent designs in steel.

No danger or disadvantage applies to the use of aluminium windows provided that care is taken to calculate the strength of the window and to make the design strong enough to resist wind loads.

If inadequate aluminium windows are installed in high rise buildings and breakage occurs at a time of high wind loading then glass can fall from a great height into the street below. This can cause serious injury or death. The subject is thus important.

Discussions were held between the expert and the Counterparts. This part of the discussion was primarily with Mr. Li Ruihua. The expert has great respect for the expertise and knowledge of Mr. Li Ruihua on this subject.

The methods of assessment of wind loads in the People's Republic of China and the UK were compared. The British Standards Institution publication "CP3:Chapter V:Part 2:1972:Basic Data for the Design of Buildings.Chapter V. Loading" was explained and found to differ from current practice in use in the People's Republic of China.

The British method of assessment of wind loads first requires the identification of the maximum gust windspeed likely to be exceeded on the average only once in 50 years at 10 metres above the ground in open level country. In the UK this speed, called the "Basic Wind Speed" or "Map Wind Speed" varies from 38 metres/second in the London area to 56 metres/second in the far north west. The UK is not subject to circular storms of the typhoon type experienced in tropical areas.

Before leaving England the expert contacted the Meteorological Office in Bracknell, Berkshire, UK who have records kept for 60 years from the meteorological station in Hong Kong. From these records a basic wind speed of 71 metres/second has been established for Hong Kong.

It should be noted that the maximum gust speed in this context is measured for a 3 second period and hence the figures appear to be high. However, a gust of short duration is sufficient to damage a window.

The Meteorological Office in Bracknell could not supply the expert with any windspeeds for the People's Republic of China but gave the records for other areas as follows:

Area	"Basic Wind Speed" (m/s)
Korea	56
South Vietnam	49
Japan	56
Macao	56
Philippines	69

...e UK method used to determine the "Design Wind Speed" from the basic wind speed is to multiply by three factors, thus:

$$\text{Design wind speed} = \text{basic wind speed} \times S_1 \times S_2 \times S_3$$

The factor S_1 is the topography factor. The value 1.0 is used for all cases except for hill slopes or valleys where the factor may vary between 0.9 and 1.1.

The factor S_2 corrects for ground roughness and building height and varies from 0.56 for small buildings in city centres to 1.27 for buildings of 200 m height in open country.

The factor S_3 takes account of the degree of security and the building life required. Normally the value 1.0 is used, except for temporary and special buildings. The factor is statistical and there is always a probability, however small, that it may be exceeded in a storm of exceptional violence.

The dynamic pressure of the wind is calculated from the design wind speed using the formula

$$\text{Pressure} = 0.0625 \times (\text{wind speed})^2$$

This formula is exactly the same as that used by the Counterparts.

The calculated dynamic pressure of the wind is not the "design wind pressure", the pressure which the window must withstand a. its maximum loading. The design principle used in the UK is that the dynamic pressure of the wind is multiplied by a further factor in order to obtain the "design wind pressure".

The UK design philosophy recognises the effect on the window of both pressures and suctions caused by the passage of the wind over the building. The full technical explanation of this further correction factor is too complex to reproduce in detail in this report but is given in CP3:Chapter V:Part 2:1972.

A further explanation of the thinking of pressures and suctions on windows is given in an article published in the "Building Research Station Digest". The article is headed "The Assessment of Wind Loads" and was published in July 1970 as a prelude to the publication of CP3:ChapterV:Part 2:1972.

A copy of "The Assessment of Wind Loads" has been supplied by the expert to the Counterparts.

The method usually used in the UK to simplify the calculation of design wind pressure on windows is to multiply the calculated dynamic pressure of the wind by a constant figure of 1.5 to account for the combined effect of suctions and pressures on the window.

The British Standards Institution publication "Draft for Development 4: 1971:Recommendations for the Grading of Windows", which will be referred to in more detail later in this report, recommends the use of the factor 1.5 to convert the calculated dynamic pressure of the wind into the "design wind pressure". The publication warns that even the 1.5 factor may be a little low for the exceptional circumstances which can occur within 3 metres of an exposed corner of a high building.

The Counterparts informed the expert that they were designing windows to a design wind load of 240 Kg/m^2 for buildings up to 100 metres high. This is said to be similar to Japanese practice, with which the expert is not familiar.

If the basic wind speeds provided by the UK Meteorological Office, shown earlier in this chapter, are examined it may be judged that a maximum wind speed of 56 metres/second could apply to the mainland of the People's Republic of China. This would give for buildings 80 metres high in city centres a dynamic pressure of the wind of 237 Kg/m^2 and a design wind pressure of 356 Kg/m^2 by the UK method of calculation.

For example, the famous 34-storey "Centre Point" building in London which is pictured in the Pilkington (Glass Company) publication "Armourplate Suspended Glass Assemblies", supplied to the Counterparts was designed to a design wind pressure of 321 Kg/m^2. The "basic wind speed" in London is 38 metres/second.

The expert repeats his great respect for the ability of the Counterparts to perform complex calculations and agrees that the design wind load of 240 Kg/m^2 will be safe in most cases. However, the expert recommends that the Counterparts should re-examine their information and methods of calculation to satisfy themselves that they will recognise the situations where a load in excess of 240 Kg/m^2 may be applied to the windows during storms at some time during the life of the buildings in some areas, especially those close to the coast.

B. The Strength of Aluminium Sections

The extrusions used to manufacture aluminium windows in the UK are made to UK specification H9 and heat treated (hardened) to UK specification TF. A copy of two pages of British Standard CP118:1969, Table 1 and Table 4 were supplied by the expert to the Counterparts showing the following main properties for this material:

Permissible stress in bending = 9.786 Kg/mm^2 (96 N/mm^2)

Modulus of elasticity = 6677 Kg/mm^2 (65500 N/mm^2)

Other properties of the material are given in the copy documents.

The methods of calculating the load applied to each bar of the window by the design wind pressure, used by the expert and the Counterparts appear to be identical. A line is drawn at 45° from each corner of each pane of glass. At the meeting points of the 45° lines a horizontal or vertical line, as applicable, is drawn to join the meeting points. The "trapezoidal" areas thus described attaching to each bar are considered to be the areas transmitting the design wind load to each bar.

The bars supported by the structure of the building are considered not to deflect. The limiting feature of unsupported bars is considered to be either maximum stress or maximum deflection, whichever occurs first. These criteria are used in the same way by the expert and the Counterparts.

The practice in the UK is to allow the following maximum deflections of bars not supported by the structure of the building:

For single glazed windows $= \frac{1}{125} \times$ span

For double glazed windows $= \frac{1}{175} \times$ span

These maximum deflections are specified in the British Standards Institution "Draft for Development 4:1971:Recommendations for the Grading of Windows".

These deflections apply to any glass thickness used in frames with members not exceeding 3 metres in length.

The standard used by the Counterparts allows a deflection of 1/160 for single glazed windows, only 75% of the allowable British Standard.

C. <u>The Strength of Glass</u>

The UK method used to determine the strength of the glass used in windows and doors is to refer to graphs published by the glass manufacturer, Pilkington Limited.

Graphs in a document headed "Pilkington.Wind Loading Charts" were supplied by the expert to the Counterparts. The graphs are for glass supported on all four edges, as used in windows, and do not apply to glass supported in any other ways.

The graphs include a clear explanation of their use which is not reproduced in this report.

It is UK practice to consider the strength of glass as a separate item from the strength of the window or door frame. Also it is UK practice to use the thinnest (and least expensive) glass which will withstand the design wind pressure. Windows in the UK commonly use glass of 4, 5 or 6 mm thickness.

The Counterparts explained to the expert that they use 6 mm thick glass in windows, but no explanation was given by them of their method of determining strength and no comparison with UK practice was made.

The above comments apply to transparent annealed glass only. Reference to special glasses is made under the appropriate further headings of this report.

D. The Grading of Windows

The British Standards Institution publication "Draft for Development 4: 1971:Recommendations for the Grading of Windows" is widely used in the UK by manufacturers and by the various authorities who specify the quality standards for new buildings.

This publication is referred to as "DD4" and specifies the limits for air infiltration and water penetration for different levels of design wind loading. Full details are contained in the copy supplied to the Counterparts.

The main provisions of DD4 are the selection of three grades of window for different levels of wind load. The highest grade is sub-divided into two parts:

Title of exposure grade	Test Pressure	
	N/m^2	Kg/m^2
Sheltered	1500	153
Moderate	1900	194
Severe (a)	2300	234
Severe (b)	2800	285

These grades apply to the UK where the maximum wind speed is 56 metres/second.

Air infiltration tests are made at different pressures for each of these grades. The test pressures are as follows in units of mm of water, approximately equal to Kg/m^2

Grade	Test Pressure (air)
Sheltered	10
Moderate	15
Severe	20

The standard DD4 specifies that the maximum air infiltration rate must not exceed 12 m^3/hour per metre length of opening joint.

It is common in the UK for air conditioned buildings to specify a lower air infiltration rate than 12 m^3/hm, sometimes as low as 3 m^3/hm, or at different test pressures.

The full discussion of air infiltration limits is too involved to reproduce in full in this report. A good summary is given in the book entitled "Windows - Performance, Design and Installation" by H.E. Beckett and J.A. Godfrey, published by Crosby, Lockwood, Staples, London in association with RIBA Publications Limited (1974).

Copies of pages 90-95 of this book, dealing with air infiltration, were given to the Counterparts.

The authors both work at the Building Research Station in Garston UK. Mr. Beckett is a physicist and Mr. Godfrey is an architect.

It should be noted that casement windows are capable of being designed to a much higher standard of air tightness than sliding windows. There is always an air leak in a sliding window at the top and bottom of the meeting rails.

Similar tests apply for water penetration. The test pressures are:

Grade	Test Pressure (water)
Sheltered	5
Moderate	15
Severe	30

The standard specifies that no gross leakage (serious leackage) should occur at these pressures. For some special buildings in the UK higher test pressures up to 50 Kg/m^2 are required.

E. Methods of Testing

British Standard 4315:Part 1:1968 describes the method of testing for resistance to air and water penetration. The standard gives complete details including the constructional details of the test equipment. This equipment is also used for strength testing.

A copy of the standard was supplied to the Counterparts who may decide to use the information to construct a test rig rather than to import the equipment.

It is common practice in the UK to test new window designs on the type of equipment described in BS4315.

During production of windows an occasional test, perhaps once every 6 months, is made on a window selected at random from the regular production. Care must be taken to ensure that the sample is taken at random and that no special care has been taken during manufacture because it was known in advance that the window sample was to be tested.

If the Counterparts decide to use this arrangement for sample testing there may be no need to install an expensive test rig at each factory. A central test facility can be used. Inspection during production (not testing) is covered in later sections of this report.

The Counterparts informed the expert that at present they have no means of testing windows for strength at their full design wind load. The expert proposed that the final design of windows can be tested for strength by making a sample window of the maximum size to be used. The sample window is to be supported horizontally in a wooden frame and loaded to the maximum by placing bags of sand evenly over the surface of the window to represent a load of 240 Kg/m^2.

The deflection of the window is to be measured under the weight of the sand. The expert re-states that for single glazed windows a deflection in excess of 1/125 of the span is considered to be dangerous in the UK. The lower limit of 1/175 applies to double glazed windows since double glass units will not tolerate as much bending as single glass.

F. Cleaning and Safety

The British Standard Code of Practice CP153:Part 1:1969 gives the UK recommendations. A copy of the CP153 was supplied to the Counterparts and the provisions are not reproduced in full in this report.

The basic provisions of CP153 are:

Sizes and types of window which can be cleaned from inside or outside of the building.

Safety catches to prevent persons falling from windows during cleaning.

Safety catches to prevent children opening windows far enough to fall out.

CP153 makes reference to another publication "British Standard Code of Practice CP152-Glass for Buildings". A copy of this document has not been supplied to the Counterparts because it is soon to be re-issued as British Stardard BS6262". The Counterparts may wish to collect a copy of this standard during their proposed study tour or to send an order to the British Standards Institution for the final document when it is published. A small charge will be made for the document.

One of the main provisions of CP152 is that in public buildings glass which is fitted close to floor level, usually in doors, must be toughened glass because of the danger of breakage of annealed glass.

The British Standard BS6206:1981 is the UK specification for performance requirements and methods of testing of safety glass for use in buildings The standard also gives constructional details for the test equipment required. The equipment used is very simple. Normally in the UK the glass manufacturer has the glass testing equipment and not the window manufacturer. A copy of BS6206 was supplied to the Counterparts.

Fire resistance of glazed aluminium products is described briefly in the leaflet "Pilkington-Wired Glass", supplied to the Counterparts. Wired glass has a higher fire resistance than ordinary glass but where a high degree of protection against fire is required neither glass nor aluminium are used in the UK.

It is the law in the UK that doors with spring closers must be fitted in corridors of public buildings to slow down the spread of fire and smoke. The expert saw no such precaution in the hotel in Guangzhou.

G. Acoustic Performance of Windows

A simple explanation of the sound insulation measures taken in the UK is as follows:

Traffic noise is mainly low frequency at a pressure level of about 75-80 dB. Gas turbine engines of low flying aircraft produce higher sound pressure levels and "quiet rooms" at airports need special design.

The recommended noise levels for rooms in the UK is

Conference room	30 dB
Bedroom	35 dB
Office (private)	50 dB

A window with 5mm glass produces an insulation of about 20-25 dB and is worse for frequencies of less than 200 Hz.

Provided that the window design does not have excessive air leakage the design of the window will not affect the sound insulation since the noise comes through the glass.

The noise insulation of a single glazed window is improved if the glass thickness is increased.

The noise insulation of a single glazed window is not improved significantly by using a double glass unit if the air space between the two panes of glass is less than 50 mm.

Two single glazed windows fitted as a double window with an air space of 150-300 mm between them and with insulating material on the edges of the cavity will produce a sound insulation of 40-45 dB. The air sealing of the windows must be good.

A more complete explanation of the acoustic performance of windows than is possible in this report is given in the book by Beckett and Godfrey mentioned earlier in this report. Copies of pages 106-116 of this book dealing with this subject were given to the Counterparts.

H. Thermal Performance of Windows

Samples of extrusions containing a "thermal break" were given to the Counterparts. The thermal break is a plastic section in the extrusion which greatly reduces the amount of heat which can be conducted by the extrusion.

These sections are used where very low outside temperatures apply. They help to prevent condensation forming on the cold surfaces of the aluminium window rather than to prevent the loss of heat from the building.

The Counterparts and the expert agree that this design feature is not needed in the areas where the windows will be installed in the south of the People's Republic of China.

The expert asked the Counterparts to consider that bronze anodised aluminium which is exposed to strong sunlight will reach a high surface temperature. Care needs to be taken with the use of small components made from plastics which soften at fairly low temperatures in this situation.

Double glass units with an air space of 6 mm will transmit about 61% of the heat passing through single glass under normal conditions.

Increasing the air space from 6 mm to 12 mm will change the percentage to about 54%.

The very wide cavities up to 300 mm used for noise insulation have a similar thermal performance to smaller cavities.

Strong sunlight on glass will produce heat inside the building by the "greenhouse effect" of solar gain. It is common practice in the west to use special glass to reduce this heating effect of the sun, especially in air conditioned buildings, so that the load on the air conditioning system is reduced.

The brochures "Pilkington-Solar Control Glasses" and "Pilkington-Insulight Double Glazing Units" give full details of solar control glass in single and double glass units. These brochures were given to the Counterparts.

An additional method used to control solar heat gain is by shading the windows, as is done in the Jubilee building in Hong Kong - see page 10 of the solar control glass brochure.

A special window is used in some buildings in UK, Europe and Japan. This is the 'Elumin' environmental control window. The brochure for this was supplied to the Counterparts.

It is normal in the UK to lock the windows in an air conditioned building so that the occupants can only open the windows for cleaning. The air conditioning systems are designed to operate with the windows closed. Opening the windows reduces the efficiency of the air conditioning system.

I. Surface Treatment of Aluminium

The Counterparts were given a copy of "British Standard BS3987:1974: Anodic Coatings". This standard gives complete details of the inspection, testing and maintenance of the anodized finish applied to windows and doors.

The standard of anodic coating used in the UK for windows and doors is 25µ (microns) thick. Experience in the UK is that a film thickness of less than 25 microns is not durable.

The expert has no knowledge of the level of alkaline air pollution in the People's Republic of China where a different coating thickness may be appropriate. The Counterparts have stated that they specify a thickness of 12 microns at present.

The expert reported the experience in the UK when aluminium products are used to enclose swimming pools. The outside temperatures and heating of the pool water cause considerable condensation on the windows. The water in pools in the UK is treated with chlorine as a health precaution. The alkaline condensation in swimming pool windows causes a rapid breakdown of anodized finishes.

It is common in swimming pools in the UK to specify stoved organic finish (paint) on the windows. This finish is widely used for other applications. The "British Standard BS4842:1972 for Organic Finishes" was supplied to the Counterparts.

Sample extrusions with anodized finish to 25 microns and organic finish (paint) were supplied to the Counterparts.

For internal partitions and furniture in the UK it is acceptable to use less than 25 micron anodizing. 15 and 10 micron finishes are specified where external pollution carried in rainwater does not apply.

J. Tolerances

The Counterparts reported an achieved accuracy of the dimensions on extrusions of ± 0.15 mm. The same tolerance applies in the UK.

The cut lengths of window bars in the UK are manufactured to a tolerance of ± 0.5 mm. Some manufacturers have electronic controls on saws which maintain an accuracy of ± 0.1 mm on length.

K. Vibration

The expert does not know of any problem with windows and doors in the UK or other western country caused by vibrations or vibrating loads. Western manufacturers do not consider it necessary to take any precautions against such problems other than to ensure that the open sashes of casements are held securely.

L. Ambient Temperatures

The Counterparts reported ambient temperatures in the range of $-7^{o}c$ to $+42^{o}c$. The expert considers that this temperature range will not cause problems for aluminium doors or windows but repeats the opinion concerning heating of sections by direct sunlight, especially when a dark anodized finish is used.

On large structures allowance must be made for the thermal expansion of aluminium. This will not apply to the products under discussion unless they are coupled into long ranges. In this case sliding couplings must be provided.

M. Buildings in the United Kingdom

There are pictures of large buildings in the UK and elsewhere in the product brochures given to the Counterparts. These buildings commonly use vertical sliding or pivot (reversible) windows. The selection of these window types is the judgement of the architects and is not considered to conflict with the Counterparts decision to use horizontal sliding windows and casements.

N. Specifications for Windows

The Counterparts were given a copy of "British Standard BS4873:1972: Specification for Aluminium Alloy Windows".

This standard is the complete standard for all aspects of the windows. Reference is made to many of the other standards mentioned earlier in this report.

The Standard includes the specification of operating loads and the accidentally applied point loads which must be resisted.

The preferred range of sizes for each type of window are given.

P. Other Background Documents

The expert was limited to 30 Kg of baggage on this mission and could not bring more than 20 Kg of documents and samples. The following standards have not been brought since they were not considered to be as relevant as the others, from the information available to the expert before leaving UK.

BS 1474	Aluminium Alloys - Extruded Sections
BS 5286	Aluminium Sliding Doors
BS 4255	EPR Gasket Material
BS 5713	Hermetically Sealed Double Glazed Units
BS 952	Glass and Glazing
CP 152	(being revised - to be issued as BS 6262)

The book by Beckett and Godfrey mentioned in this report has been given to the Counterparts after the expert received authorisation from the UK library who previously owned the book. Further copies of this book and the other standards and literature can be obtained from the publishers if required.

4. COSTS

The expert has been trained in an environment where product costs are of paramount importance, since western businesses must operate profitably and must compete with each other.

This attitude may not apply in the same way in the People's Republic of China and the Counterparts are asked to recognise that this may affect the opinions offered by the expert.

The training of the expert has been to eliminate all costs which do not contribute to the performance or aesthetic qualities of the product.

5. PRODUCT STANDARDS SPECIFIED BY THE COUNTERPARTS

The Counterparts have specified three different standards for their products.

Luxury	The standard appropriate to rooms used by foreign government officials
Tourist	The standard appropriate for foreign guests and tourists and overseas Chinese
Economy	The standard appropriate for housing and hotels for local Chinese people, including meeting rooms for Chinese business peopl

These standards seem to be a sensible cho expert who can offer no further comment.

The expert offered the suggestion that the Counterparts may wish to consider the following product specification to meet the selected standards.

Luxury	Horizontal sliding windows and balcony doors in coloured anodized finish. Double windows and doors with 150 mm or more cavity and solar control glass in the outer products. This will give the best possible appearance, privacy and control of the environment.
Tourist	Horizontal sliding windows and balcony doors. Natural anodized finish. Balcony doors to be shaded by the balcony of the room above to reduce solar gain. Clear glass.
Economy	Simple casement windows. Natural anodized finish. Single clear glass. It is possible that a low-cost sliding window of limited size could be designed for this application.

6. EVALUATION OF THE HORIZONTAL SLIDING WINDOW DESIGN PRODUCED BY THE COUNTERPARTS

The sliding window design produced by the Counterparts is similar to some imported windows used in tourist hotels in the City of Guangzhou. Finished windows installed in buildings as well as design drawings were examined.

The designers allocated to the project were highly skilled and only the principles of suggested design improvements needed to be explained by the expert. Many good ideas for the improvement of the design details were produced by the Counterparts during the discussions.

The agreed changes made to the original design are summarised as follows:

Changes to the outer frame head and cill to prevent the sashes accidentally falling out of the frame, or being sucked out by negative pressure.

Increased meeting rail strengths to suit the design wind pressure.

Increased outer frame cill height to improve water sealing.

Outer frame head made in two pieces to allow the window to be serviced or repaired from inside the building.

Addition of a transome bar to allow the use of the casement design in conjunction with the sliding window design. This eliminates the need to make special fastlights for use with the sliding window.

Two optional versions of the outer frame cill to allow the design to be used either as a sliding window or as a balcony door. The water sealing of the window will be much better than the balcony door which should not be installed in exposed positions.

Woolpile seals moved from the sashes to the outer frame to improve performance and appearance.

Corner joints of the sashes re-designed to simplify manufacture and improve appearance.

Sashes moved closer together to reduce cost and improve appearance. This change also eliminates from the design two sections which would be very difficult to extrude.

Simplified fittings and a safety catch were discussed but not designed in final detail.

Maximum width of a single unit limited to a maximum of 3 metres. Units larger than this to be made by coupling two smaller units.

7. EVALUATION OF THE CASEMENT WINDOW DESIGN PRODUCED BY THE COUNTERPARTS

The agreed changes made to the original design are as follows:

New transome with weatherbar added to suit the design wind pressure.

Muntin (mullion) strength increased to suit the design wind pressure.

The weak cross-jointing of muntins eliminated.

Seal gasket on the inside changed to improve water sealing.

Corner jointing of gaskets specified to use Loctite IS 414 Cyanoacrylate Adhesive. A sample of this special adhesive was given to the Counterparts.

Outer frame changed to mitred corner joints to improve sealing.

Double handles replaced by single to improve appearance and reduce cost.

Fittings material changed from Mazak to aluminium to improve quality and appearance.

Sash changed from inside glaze to outside glaze to improve appearance.

Corner jointing by crimped cleats to simplify manufacture.

Coupling details changed to match the sliding window.

8. DOOR AND ENTRANCE UNITS

Brief discussions of the design of door and entrance units made from imported material did not extend to a full evaluation of the design. The expert gave the Counterparts three brochures from James Gibbons Windows Limited in England. These brochures describe in detail the high quality "Slimline" products which are used extensively in the west for doors, entrance units and "ground floor treatments".

In the short time available to the expert to examine the products of this type the main recommendation is to re-design the bead of the fastlight similar to the "Slimline" system to improve appearance and to eliminate the need to drill many screw holes.

9. COUPLINGS

The Counterparts had not spent a lot of time on the subject of couplings. The methods of calculation of strength were explained in detail to enable the Counterparts to produce designs of couplings which will allow any required size of window to be made by coupling several units together.

The particular points needing care are as follows:

Water sealing to prevent the internal finish of the building being spoiled by water penetration at the coupling.

Allowance for thermal expansion by sliding joints where necessary.

Sufficient strength to suit the design wind pressure, using steel sections to reinforce the aluminium where necessary.

10. INSTALLATION DETAILS

The installation details used by the Counterparts are quite different to those experienced by the expert. The expert saw no reason to criticise the methods used by the Counterparts and could offer no suggested improvements.

The need to ensure that the aluminium windows, and especially the sliding windows, are installed level and square was stressed.

11. PLANT LAYOUT

The Counterparts specified their requirement that the factory should be designed to consume 4 tonnes of aluminium extrusions per day, working one shift.

The anticipated mix of products is:

Sliding windows	40%
Balcony doors	5%
Casement windows	35%
Other products	20%

For the products which have been designed this is equivalent to 635 m^2 of products per day. This figure is quite different to the output rate specified in the Project Document.

The manufacturing plan calculations allow 12% scrap of extrusions as off-cut waste at the saws.

The net weight of extrusions used in the typical sizes of each product are:

Sliding window	5.85 Kg extrusion/m^2
Balcony door	5.97
Casement window	5.70

The average extrusion designed has a weight of 0.85 Kg/m.

The factory is designed to manufacture 3900 finished bars per day, ready for assembly.

The stock requirements specified by the Counterparts are:

Extrusions	400 tonnes
Glass	20000 m^2
Small parts	100 days consumption

The rate of working expected as the "standard performance" by operators in western factories is that which requires the same effort as walking at 6.4 Km/hour. The climate in the People's Republic of China is such that a lower rate of working could be appropriate.

In the calculations of the numbers of machines required an attempt has been made to allow for this rate of working. The estimated time required for each operation should be adequate with the contingency included. The detailed calculations are not reproduced in this report but are left at the factory for the engineer who will undertake the next part of the mission.

For the production of sliding windows and casement windows every operation has been planned in detail and the required machines and tooling have been listed.

The numbers of machines have been determined by allowing a maximum of 70% load on any machine. This provides a further insurance against individual machines being overloaded as a result of errors in the estimates of time required for each machining operation.

The machines required for the production of doors and entrance units have not been determined by the type of analysis used for the other products. The door and entrance unit designs are not known in sufficient detail for an operation breakdown to be produced at this point in time. The expert has specified the numbers and types of machines commonly used by other manufacturers of doors and entrance units.

At the request of the Counterparts the list of machinery and equipment has been extended to include facilities for all ancilliary functions. These are:

Machine and tooling repair facilities
Die casting facility for hardware
Woolpile production
Nylon moulding
Sharpening equipment for carbide tipped saw blades

The layout of the factory to produce the aluminium products plans to use the buildings as follows:

Number one workshop 90 metres long by 30 metres wide.

First side

Glass stores and cutting	630 m^2
Small parts stores	180 m^2
Small parts manufacture and machine repair	540 m^2

Second side

Sliding window machining	720 m^2
assembly	480 m^2
despatch	150 m^2
	2700 m^2

Number two workshop - identical to number one.

First side

Casement window machining	510 m^2
Frame cleating	240 m^2
Assembly	330 m^2
Despatch	270 m^2

Second side

Door and entrance machining	580 m^2
Assembly	500 m^2
Despatch	270 m^2
	2700 m^2

Number three workshop - a new building in process of construction 72 metres long by 30 metres wide

Extrusion unloading area	480 m^2
inspection	250 m^2
storage	720 m^2
sawing	710 m^2
	2160 m^2

Separate buildings and areas are required for the following:

Air compressors	these machines are very noisey and are to be separated from the production area. A temporary compressor is planned until a decision is made on an anodizing facility, which will need a large volume of compressed air.
Die casting facility	the heat generated by this operation demands a separate building.
Window test rig	if the decision is made to have this facility at the factory.
Scrap aluminium storage	
Scrap glass storage	

The detailed layout of the factory and listing of equipment are too complex to include in this report.

The list of machines and equipment required needs considerable further work to negotiate the engineering details and prices with the machine suppliers. This work was not part of this mission. Without this task being completed it is very difficult to estimate the costs of the equipment to be imported. The expert has attempted to guess the costs including shipping and installation costs. The figures can only be very approximate but are summarised as follows in United States Dollars:

Extrusion stores and saws	124000
Sliding window - machining	114000
- assembly	4200
Casement window - machining	120000
- assembly	32400
Entrance units - machining	37000
- assembly	7000
Small parts manufacture - aluminium	42000
- nylon	47000
Total US $	536600

This very rough estimate of costs is 18% higher than the budget figure of $454700 but the estimated costs may be too high. The only conclusion which can be drawn from the estimated costs is that the budget figure and the estimated costs are of the same order.

The capacity of this equipment is to produce 635 m^2 of products per day. This is much higher than the output specified in the Project Document.

No attempt has been made to estimate the cost of building work and equipment to be provided by the People's Republic of China.

The layout of the extrusion stores has demanded a change of design of the number three workshop now in process of construction. The clear height under the crane must be at least 6.5 metres.

The overall design of the factory has been for a level of automation less than that found in a motor car factory, for example. The machines selected are the most modern and automatic known to the expert. The transfer of components between one machine and the next is not planned to be automated because of the complexities involved in making windows and doors of many different sizes. The large investment which would be involved in the automatic transfer of work between operations is not considered to be appropriate to this factory.

The safety standards imposed on machines in the existing factory are not satisfactory by western standards. The new machines and tooling selected, especially the presses and tooling, are such that the operator's hands can not be trapped by the machine.

The expert recommends the following precautions for the new factory: Presses to be set to the smallest stroke which the tooling will allow. This will generally be less than 12 mm. This will prevent accidental trapping of the operators'

hands. Presses with tooling needing a larger stroke must be guarded.
Operators using saws emitting loud high-frequency noise should wear ear defenders.
Operators of saws, routers and drills should wear eye protection.
Female operators of rotating machinery should be instructed to tie up their long hair so that it can not be caught by the machine.
In the glass cutting area and areas where glass is being handled at least one person should be instructed in simple "first aid" methods to stop bleeding from severe lacerations which may result from accidents with glass. The necessary medical supplies must be kept close to the working area.
The floors of workshops where high speed machines or glass are used must be kept free of loose cables, airlines, scrap material, etc.

The Project Document anticipated that 80 personnel would be required in the factory. Now that the factory has been designed and the level of output decided an approximate listing of personnel required indicates a total of about 350 people, including site installers.

12. FUTURE DEVELOPMENTS

The Counterparts have stated that they are considering the installation of extrusion and anodizing facilities at the Guangzhou factory.

At present extrusions are transported great distances to reach the factory. The project report headed "Preparatory Assistance" dated May 1981 mentions problems of quality of extrusion and anodizing. It appears that the Counterparts have resolved these problems to a large extent but the transportation from distant extrusion plants remains a problem.

An extrusion press of approximately 1600 tonnes capacity would produce the extrusions required by the window and door factory. The output rate of such an extrusion press would be about 4 tonnes per shift. This is equal to the consumption rate of the factory.

An anodizing plant capable of processing 4 tonnes per shift would complete the site. The plant should be equipped to produce 'Anoloc' or 'Calcolour' or an equivalent bronze colouring. Colours produced by the simple method of using dye have proved to be unsatisfactory in the west.

The expert recommends that the following major factors should be considered by the Counterparts before the final decision is made:

Water supply — a large volume of water will be required for the anodizing plant. It is recommended that the chemical composition of the site water be checked for its suitability for use in the anodizing plant.

Effluent — a large volume of toxic effluent from the anodizing plant needs to be removed.

Electricity — the anodizing plant heaters for the etch and seal tanks will need to be electric as no gas supply is available on the site. The power consumption of these heaters and the refrigeration plant for the anodizing tanks and the motors of the extrusion press will combine to form a considerable electrical load.

Personnel — the extrusion press needs highly skilled people to manufacture the dies. The quality of the extrusions will depend more on the skill of these people than on the quality of the extrusion machinery.

The opinion of the expert is that the product designs could be developed as follows:

Entrance Units — a comprehensive range of sections and associated components to produce doors and entrance units perhaps similar to the "Slimline" product mentioned in this report.

Sliding Windows — a lighter and more economical product for less luxurious buildings.

Casement Windows — a more robust design suitable for high rise and prestige buildings.

Further assistance may be needed to design the control systems for the factory.