THE WOLFSON CENTRE

For Bulk Solids Handling Technology

Report R/1894/3

BIN DESIGN WORK WITH
DAMP FGD GYPSUM POWDER

for

British Gypsum Ltd.
East Leake

September 1993

University of Greenwich
London

The Wolfson Centre for Bulk Solids Handling Technology

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1. INTRODUCTION

1.1 Contractual

The proposal relating to this work was Wolfson Centre reference P/1894/2 of 2nd July 1993, in respect of which British Gypsum purchase order number 79/CAP3977 covers items 1 to 3 inclusive, whilst fax. ref. BG Dale 21st July 1993 requested action on items 4,6, and 8.

1.2 General technical requirement

The technical requirement of this project was to obtain the flow properties of a damp FGD gypsum powder, and from these predict the critical arching dimensions and hopper half angles for hoppers to discharge the contents under gravity, possibly after a period of undisturbed storage. Three wall conditions were to be considered, i.e. Cromweld 3CR12 Stainless with a 2B finish. Poly Hi Solidur "Tivar-88" ultra-high molecular weight polyethylene, and concrete with a plain shuttered finish.

This information was to be used to provide technical recommendations in respect of outline design of a ground hopper and its chain conveyor extractor, and recommendations for the design of chutes for the material.

1.3 Material to be handled

The material to be handled is an FGD gypsum powder with a moisture content of up to 10% by weight. It was intended that the designs should as far as possible allow the handling of material of a moisture content which gives the highest resistance to flow, within this range.

2. EXPERIMENTAL WORK UNDERTAKEN

2.1 Gypsum materials used for testing

Four samples of gypsum were supplied to The Wolfson Centre by British Gypsum Ltd. These had moisture contents of 6.03%, 9.47%, 18.4% and 20.2% nominally by weight. Since the latter two were out of range of specification of the handling equipment, these were discounted for the purposes of design and testing, and a limited programme of shear tests were made to identify which of the other two, i.e. the 6.03% or the 9.47% moisture content samples, was worst from the point of view of handling.

These tests did not reveal any significant difference between the two material samples, so the sample with the 6.03% moisture content was selected for further testing.

Subsequent to the completion of testing, another sub-sample of the material used was returned to British Gypsum Ltd. for moisture analysis, the results from which showed a moisture content of 5.03% by weight, so it was evident that some drying-out had occurred during the testing.

2.2 Wall materials

Wall friction tests were undertaken against two materials, firstly Cromweld 3CR12 stainless steel with a 2B finish (cold rolled between polished rolls), and secondly Poly Hi Solidur "Tivar-88" ultra-high molecular weight polyethylene. It was necessary to undertake wall friction tests for the concrete, this being considered as a rough wall (see section 3.3 below for further explanation).

2.3 Test equipment used

An annular shear cell of the Walker pattern was used for measurement of the internal shear properties of the powders. A modified Jenike type shear tester was used to measure wall friction. Larger sample plates of wall materials were used for confirmatory tests on the chute design recommendations.

2.4 Test conditions

All tests were undertaken at ambient conditions of temperature and humidity, using product in a condition as supplied, as agreed with British Gypsum Ltd.

2.5 Experimental programme

Both the 6.03% and the 9.47% moisture content samples were subjected to a limited programme of shear cell tests consisting of 21 test points at the upper and lower ends of the usual range of normal stresses. Following these tests, sub-samples were extracted from each of the test samples, and these sub-samples returned to British Gypsum for checking of moisture content, in order to eliminate any suspicions in respect of actual moisture contents and/or of any drying out during testing.

Having selected the sample with 6.03% moisture for further testing, this was then subjected to a comprehensive programme of shear testing to obtain its instantaneous flow function. A time flow function was performed with a 24 hour duration; this gave some hope that a design may be possible to discharge the material after such a residence time, so a further two 24 hour time consolidation tests were carried out to obtain the flow function relating to this time consolidation period.

Wall friction was measured under instantaneous conditions against both Cromweld 3CR12 stainless steel with a 2B finish (cold rolled between polished rolls), and "Tivar-88" ultra-high molecular weight polyethylene. The compaction curve of the powder was measured in a cylindrical cell of diameter much greater than height.

Chute angles as calculated were checked by using a piece of "Tivar-88" plate approximately 300 mm by 200 mm. The gypsum was placed onto this in a number of conditions ranging from loosely poured through lightly compacted to a very heavily compacted, and in each case the angles required for the material to move and to clear were noted. Small bed depths ranging from 20 mm to 40 mm were used for these tests, these being a worst case because the effect of adhesion causes an increase in the effective angle of wall friction at low stresses.

3. TEST RESULTS AND ANALYSIS

3.1 Flow Properties

The data obtained was analyzed to obtain the flow properties of the product, which are illustrated in Appendix A.

From these flow properties, the hopper convergence angles required for mass flow, and the maximum arching dimensions were calculated for conditions of gravity discharge.

3.2 Time consolidation

Time consolidation appears to be very severe with this material, even for the 24 hour condition tested.

3.3 Wall friction and adhesion

The material displayed a very strong adhesion to the Cromweld 2B sheet, sufficient to result in extremely high effective angle of wall friction at the low stresses occurring in hopper discharge. The "Tivar-88" material performed much better in this respect.

Concrete with a plain shuttered finish was considered to be effectively a "rough wall", i.e. having sufficient roughness to preclude the development of a clean sliding plane between the wall and the powder, leading to shearing in the powder close to the wall and hence an effective angle of wall friction equal to the effective angle of internal friction of the powder.

3.4 Critical dimensions for instantaneous discharge

Resulting critical dimensions, based on the samples tested, are as follows for instantaneous discharge (i.e. when material is kept moving at all times):-

Angles of sides to vertical required to achieve mass flow against "Tivar-88" sheet, and critical arching dimensions:-

Conical hopper - angle 17°, arching dimension 0.51 m

Wedge hopper - angle 30°, arching dimension 0.25 m

With Cromweld 2B, the high adhesion of the gypsum to this wall material precludes mass flow. Consequently, because the critical rat-hole dimension for core flow (although not calculated) is expected to be much larger than the arching dimension for mass flow, it is not possible to design a converging hopper with a Cromweld 2B lining to discharge the damp gypsum under gravity.

For concrete with a plain shuttered finish, based upon the "rough wall" condition described above, again it is not possible to design a converging hopper with this wall to discharge the damp gypsum under gravity.

3.5 Discharge after time consolidation

The additional strength gained during the 24 hour time consolidation tests was very high, increasing with higher stresses, and the 24 hour time flow function obtained is such as to prevent the design of a converging hopper to discharge the material under gravity after this period of time, even with the "Tivar-88" lining. This effectively means that to be able to discharge under gravity after 24 hours of residence would require a parallel sided channel with a fully live bottom.

The question which arose from this finding was as to what period of time consolidation may still allow discharge. Taking the amount of additional strength gained in 24 hours and halving it, such a condition would allow discharging from a "Tivar-88" lined hopper with an outlet dimension approximately double those quoted above for instantaneous discharge. Given that the scheme suggested in 4.1 below has a minimum dimension in approximately this range, there is clearly the potential to accommodate some time consolidation. The exact time period which this relates to is not certain; the rate of gain in strength will not be linear with time but will increase more quickly initially. No tests have been done to assess the rate of time consolidation with this material, but it is likely that the time to gain half the strength gained in 24 hours will be in the region of between four to eight hours approximately, judging from experience with other damp mineral powders.

4. COMMENTS UPON PROPOSED SCHEME FOR GROUND HOPPER

4.1 Hopper geometry

British Gypsum Ltd. proposed an outline scheme for the ground hopper arrangement in a fax of 29th July 1993, which is reproduced in Appendix D. This involved a double hopper arrangement with four outlets onto a chain-and-flight feeder. The Wolfson Centre expressed concern at the operability of this arrangement as proposed, and suggested certain modifications to obtain increased reliability of flow. These were communicated in a fax of 6th August 1993, following which discussions between The Wolfson Centre and British Gypsum Ltd. led to the decision to change the outline to a single hopper with one slotted outlet onto the chain-and-flight feeder.

Subsequently The Wolfson Centre submitted drawings giving suggested features to be incorporated into such an arrangement, initially in the form of unissued prints of drawings nos. D/1894/2 sheets 1 and 2. These drawings have now been modified and issued, and are reproduced in Appendix B. It is most important that the recommended features shown on these drawings are adhered to if reliable flow out of the hopper is to be obtained with materials as tested. Particular features which should be noted are as follows: -

(I) the width, length and taper angle (5° half angle in plan) of the outlet slot, and the rising angle of 5° on the bottom edges of the long walls;
(ii) the angles of all hopper sides to the vertical, i.e. 27° on the side flanks and 14° on the end walls;
(iii)the stipulations as to lining materials, i.e. "Tivar-88", and the avoidance of intrusions into the flow space;
(iv) the 200 mm wide fillets across the internal valleys, again lined with the same materials as the sloping hopper walls;
(v) the 1500 mm width of the conveyor, in the actual flow channel, with a 1/2° divergence of the side walls along the length; and
(vi) the avoidance of use of a gate at the outlet end which could be lowered below the bottom edge of the hopper side illustrated.

Should there be any deviation whatsoever from these recommendations, then it is most important that the Wolfson Centre is consulted before incorporation of such deviations, because the obtaining of reliable flow (with gypsum material as tested) depends critically upon each of these details being observed.

4.2 Coping with longer time consolidation

Should the material remain in residence undisturbed for a period of time in excess of that which gives half of the strength increase observed in 24 hours (see section 3.5 above), it is likely that flow will not restart when the extractor is started, as the gypsum will bridge over the hopper outlet. To overcome this, the gypsum will need to be disturbed in the hopper; once it has been subject to a significant disturbance then its strength will return to the instantaneous value and flow will become re-established. The amount of energy required to achieve this will be considerable.

One suggestion which has been made for achieving this disturbance is to apply vibration to the side walls of the hopper. However, it is felt that this could cause more problems than it solves, because of the flow characteristics of the material. The damp gypsum has a very steep flow function, which means that compressing the material when it is confined makes it a good deal stronger, and when the compression is released it remains strong. The vibration will thereby cause further consolidation of the material above the arch in the hopper and make it even harder to discharge. Thus for vibration to be effective it must be applied adjacent to, or only just above, the point where the material is arched, and not to the main body of bulk solid further up in the hopper. Initially this means the bottom of the hopper side only, but as the material begins to flow it may be necessary to apply the vibration further up. The difficulties involved in achieving this effectively, and the dangers of making the material even harder to move, will be obvious from this, and hence the use of vibration is not recommended.

The most effective way of applying a disturbance for the purposes of encouraging the initiation of flow of time-consolidated material, would be to mount one of the long side panels of the hopper on flexible mounts to allow it to move a significant amount relative to the rest of the hopper, and apply motion to this at a very low frequency, with a large displacement. This could be achieved with pneumatic cylinders or hydraulic rams, but again it is important that the motion is transmitted all the way to the bottom of the sloping panel. An alternative solution, which may be more effective, would be to mount one of the long sloping side panels of the hopper on a hinge along the top edge, with an hydraulic ram to push the bottom edge of the panel in and then allow it to return to its normal position; this presents certain problems in terms of ensuring no interference with the extractor below the hopper, and also in obtaining a suitable seal against the end walls of the hopper. In either case, the moving part of the wall must extend all the way to the bottom edge of the hopper side panel and for the entire length of the panel. This would effectively provide the mechanical work required to make the material flow, gravity alone being insufficient to do so. The structural implications of such a design are not insignificant and must be considered carefully, but it is felt that such a solution would give the best chance of success.

Another alternative way of overcoming this problem, which may prove more cost effective, is to ensure that long time consolidation does not occur. Provided that at least a little material is extracted frequently, the problem will be avoided, and it may be possible to do this even during breakdowns of plant further downstream, by arranging for a diversion of material from some point in the flow path between this hopper and the plant, where the gypsum can be dumped out onto the ground, or into a standard container, for collection and return to the stockpile. In terms of effectiveness and reliability it is felt that this solution would be far better than the other possible solutions proposed above, none of which is really reliable. Control of dust from such a diversion point would need to be considered if it is possible for the material to become sufficiently dry to be dusty at any time, and of course the safety aspects of the arrangement would also need to be properly considered.

4.3 Trash grid on top of hopper inlet

It is understood that there is a desire to place a grid above the hopper inlet in order to prevent tramp material from entering the hopper and damaging the equipment. Although it is not possible to make a definitive analysis of the minimum size of this grid, it is the opinion of The Wolfson Centre that the aperture of grid used should certainly be no smaller than 125 mm square, and that frame of the grid should be mounted on flexible mounts and fitted with vibrator units, to break the bridging which will inevitably occur across the holes in the grid. It is also important that the frame of the grid is mounted in such a way that it can be hinged open or lifted off to provide access in case a blockage occurs in the ground hopper, as a result of excessive time consolidation or the feeding of material with excessively bad flow characteristics.

From the point of view of not impeding flow more than necessary, a grid of parallel bars will be more effective than a square grid, but of course this will be less effective at catching tramp material. In any case, the elements of the grid should be as small as possible, although of course this requirement must be traded off against that of obtaining sufficient strength, particularly bearing in mind that the forces acting on the grid will be considerable when bridging across the holes in it occurs. Possibly the best way of trading off these conflicting requirements would be to employ parallel bars of thin rectangular cross section, standing on edge at a minimum clear spacing of 125 mm, with small diameter rods across at right angles, again with similar minimum spacing.

5. RECOMMENDATIONS FOR CHAIN-AND-FLIGHT FEEDER

5.1 Deck plate material

Because the gypsum is damp and it is possible for it to remain static in contact with the deck plate of the feeder for some period of time, in the case of a stoppage with material in the ground hopper, it is recommended that the deck plate material used is resistant to corrosion. This will make a considerable reduction in running and particularly start-up torque under such circumstances, because if the deck plate was to become rusted over a period of time with the damp gypsum in contact with it, then this would effectively lead to a "rough wall" condition here, the feeder having to shear the gypsum internally rather than against the wall. This internal shear requires considerably more force than shearing of the gypsum against a clean, smooth metal surface. A relevant point here is that the gypsum is unlikely to be very abrasive in nature, and so once the surface has rusted, it will not smooth down again quickly when operation resumes, as would be the case if handling say coal. Consequently it is recommended that a stainless material is used for this deck plate, for example Cromweld 3CR12 which has adequate corrosion resistance yet is cheaper to buy and fabricate than a true authentic stainless such as 304, 312 stainless etc.

The surface finish of the material used for the deck plate is also of great importance, and should be either one of two particular finishes available from Cromweld Steels, i.e. a 2B finish (available on material up to 5 mm thick) or alternatively a Bunker Polish finish (available on thicker materials) mounted with the direction of finish parallel to the direction of flow of gypsum.

5.2 Side walls

The calculation of hopper sizes, etc. are base don side walls 1500 mm apart, with the material fully active between these. If proper flow is to be maintained from the hopper then it is most important that this dimension is not reduced, although any increase would not cause a problem in this respect. It is recommended that they are lined with "Tivar-88" material to reduce the running and start-up forces needed on the feeder, and it is strongly recommended that some slight divergence of the side walls in the direction of flow is allowed, say approximately 0.5° each side, to allow some dilation of the material as it flows along the bed. This will serve both to keep the power requirement down and also to promote good flow from the hopper.

5.3 Speed and feed rate requirements

Based on a nominal bulk density of 1000 $kg.m^3$ with a bed cross sectional area of 0.49 m^2 (from drawing D/1984/2, sheet 2) and a material speed equal to chain speed at all points in the bed, a chain speed of 85 mm/s (5.1 m/min or 17 ft/min) will be needed to give a gypsum delivery rate of 150 tonne/hr. Any variation of this from the nominal value will arise principally from two sources, namely (I) actual material speed in the bed being slightly slower than the chain speed as a result of some shearing inside the bed, and (ii) the bulk density in the bed being higher than the nominal value as a result of retaining some compaction from the pressures in the hopper.

The first of these, material speed in the bed, seems unlikely to vary greatly from the chain speed although no definitive information is available about this. Consequently it is felt that this is not likely to be a significant factor in comparison with variation of bulk density.

As far as bulk density is concerned, the value of 1000 kg/m^3 was based upon the depth of material in the bed and its expected compaction under self weight, based upon the measured compaction curve of the gypsum in Appendix A. In practice, however, the material which has just been removed from the hopper will have been subjected to a higher compacting pressure so will have had its bulk density increased, making the figure of 1000 kg/m^3 a lower limit. Based on the pressure calculated for the calculation of feeder drive power, the bulk density under such pressures (extrapolated slightly from the measured compation curve) could be as high as 1500 kg/m^3 in the hopper outlet. The material in the centre of the feeder channel, directly under the hopper, could in principle reach such a bulk density, although that falling onto the feeder outboard of the hopper outlet will have a much lower bulk density, probably of the order of 900 kg/m^3, giving a median bulk density of 1380 kg/m^3. This is felt to be very much an upper limit value, because the material will have been subject to shearing as the feeder takes it away from the hopper, inevitably causing some expansion.

Given the feed requirement of 150 tonne/hr, if a feeder of 1500 mm operational width was geared to give this feed rate based on the lower limit of bulk density (5.1 m/min chain speed), then the upper limit of feed rate will be 38% higher at 207 tonne/hr, at the upper limit of bulk density. If on the other hand the feeder was geared to give the required 150 tonne/hr at a bulk density mid way between the upper and lower limits quoted, i.e. 1190 kg/m^3 (4.3 m/min chain speed), then the upper and lower limits of feed rate will be ± 19%, i.e. 122 to 178 tonne/hr.

5.4 Drive power requirements

The power required to run the feeder at 5.1 m/min chain speed is likely to be approximately 9.5 kW in the running condition, corresponding to a total chain pull of 111 kN. The start-up chain pull could be as high as four times this, i.e. 445 Kn in total, giving an equivalent power of 37 kW.

These figures are based on the correlations put forward by Bruff ("Industrisiloer, Ingeniorforlaget A/S, 1974), which generally give the highest figures for feeder loadings compared with other correlations. The effective head of material resting upon the feeder is taken as four times the mean hydraulic radius of the slot outlet (hence 1.4 metres) and the shear loads calculated from the effective angles of internal friction and wall friction, with the pressures on the side plates of the feed channel calculated based upon a vertical to horizontal stress ratio of 0.4 as recommended by Janssen. The starting loads are taken as four times the steady-state loads, again as reported in the work of Bruff.

The starting torque of a three phase electric motor when started direct-on-line is a good deal higher than the maximum running torque, so it is not necessary to rate the motor to the full 37 kW starting condition. It is, however, dependent upon the number of poles of the motor. For example if a 2-pole (nominal 2800 rpm) motor is used then the locked rotor torque will be around 2.5 times the operating torque, requiring a nominal 15 kW motor, whereas if an 8-pole (nominal 720 rpm) motor is used (to minimize the gearbox reduction ratio) then the locked rotor torque will be only about 1.8 times the maximum running torque, requiring a nominal 22 kW motor. These requirements will hold provided it is felt acceptable to overload the motor to this extent for starting. These motor requirements are approximate, and reference should be made to the motor supplier before selection of the unit is finalized.

Note that the power supply to the motor should be over-rated to at least seven times and preferably nearer ten times the rated full load current of the motor, to allow direct-on-line starting. The effect of the starting surge on any sensitive instrumentation attached to the same branch of the power supply needs also to be considered.

The gearbox must of course be sized for the full maximum starting torque, equivalent to 37 kW, because overload of this component will cause damage.

A further point worth bearing in mind is that the highest pressure in the bottom of the hopper, and hence the highest load on the feeder drive, occurs when the hopper has been filled from empty with no material being extracted. Therefore, in order to prolong the life of the drive system and the feeder chains it would be worthwhile to ensure that the feeder is always running when the hopper is being filled, especially at times when the hopper is nearly empty. Once some material has been extracted, the pressures will be reduced by virtue of the fact that the flow pattern has been established, so stopping and re-starting the feeder with material in the hopper is less of a problem. The effect of time consolidation is also relevant here, insomuch as that if the hopper is left with material in for a long period of time, particularly if it has been filled without material being extracted, the maximum acceptable feeder load could be exceeded on attempting to restart.

6. CHUTE DESIGN

The design of chutes for the damp gypsum needs to be addressed carefully because of its highly adhesive properties. All chutes should be lined with "Tivar-88" material against which, as can be seen from the wall friction results in Appendix A, the gypsum gives much lower adhesion than is the case with stainless steel. In fact the effective angle of wall friction is so high at low stresses with the stainless steel that it is completely eliminated for all but virtually vertical chutes, and of course any rougher steel will be even worse.

The shapes and manufacturing details of the chutes must also be controlled very carefully, it is strongly recommended that they are designed with a slight increase of width along the direction of flow, with the walls tapering outwards towards their top edges, and very generous radii or fillets in the corners. These features are illustrated in Appendix C. Additionally, it is essential to ensure that there are no protrusions into the flow channels whatsoever, so all lining attachment bolts must be countersunk flush (not proud or low), and joints between sheets of lining material must be either perfectly flush, or overlapped so that the steps are downwards or outwards in the direction of flow.

The lower limit of chute angle has been established to be 45° to the horizontal with the gypsum sample tested on "Tivar-88" material. This will clear the material in the condition as tested, provided that no hard impacting or time consolidation has taken place. However, it is felt that because of the natural variability of the gypsum, the shallowest chute angle chosen for use on the plant should be somewhat steeper than this.

It is also recommended that consideration be given to ensuring that the mechanical arrangements and operating procedures of all chutes are such as to avoid impaction or time consolidation of the gypsum. Angles of wall friction as high as 75° have been measured with heavily impacted material, so chute blockages could occur if such steps are not taken. The worst conditions for impact adhesion occur where material falls at high speed (e.g. from a very steep chute) onto a chute near the minimum angle, so this condition can be avoided by ensuring consistency of steepness of chutes, minimising free fall and minimising changes in chute directions and angles at transfer points to give smooth transfers. Time consolidation can be removed by ensuring that all chutes are cleared at the end of individual discharge cycles and not allowed to remain with material in them.

Failure to observe the details and precautions stipulated above will undoubtedly lead to blocked chutes.

7. LIMITATIONS ON RESULTS

Because the design data quoted above, and the general technical recommendations, are based upon the testing of the material samples as supplied, at ambient laboratory conditions, the figures and recommendations clearly relate to those samples and conditions. Should the characteristics of the material alter, possibly as a result of changes in conditions of temperature, moisture content, production conditions etc., then the flow characteristics will change and it is possible that problems may arise.

The same comments apply in terms of the representativeness or otherwise of the samples supplied, as to the effect of conditions in the plant; although every reasonable care has been exercised in performing the work, The Wolfson Centre will not be held responsible for any problems which may arise owing to the samples tested being unrepresentative of the products to be loaded into the finished plant, not owing to the effect of conditions in the plant being different from those in the test laboratory.

8 BUDGET

N/A

9. CONCLUSIONS

The following is a brief summary of recommendations laid out in this report, and is not intended to be comprehensive; for design of equipment, the detailed recommendations in the main report must be fully understood and adhered to.

9.1 Hopper design

Initially a comparison was made between two samples of damp gypsum, with moisture contents of 6.03% an d9.47%, based upon limited flow property measurements. No significant difference in flow properties was apparent between the two samples.

Following this, the flow properties of the sample with the 6.03% moisture content were comprehensively determined. Subsequent to these tests, a sub-sample was returned to British Gypsum for re-analysis, which gave a figure of 5.03% moisture. All moisture content figures were produced by British Gypsum Ltd.

Critical hopper dimensions were calculated based upon the data obtained. The results indicate that the limit of mass flow for the material tested corresponds to a conical hopper half angle of 17° to the axis with a maximum arching dimension of 0.51 m, with a nominal wedge hopper half angle of 30° to the vertical and corresponding critical arching dimension of 0.25 m. 24 hour time consolidation precludes the gravity discharge of the material from a hopper of any design, but choosing a shorter time to reduce the strength gain to half the 24 hour value results in an increase of critical arching dimension to double the above figures.

The requirement in terms of flow rates and patterns needed in the hopper have been considered in the light of the above dimensions, and based on these, a set of recommended features which should be incorporated into the final design of the hopper have been prepared, as illustrated in Appendix B. It is most important that these features are incorporated as illustrated, otherwise poor performance will result. Chief features are the angles of the sides and sizes of the slotted outlet, the lining of the angled surfaces with "Tivar-88" material, the fillets in the corners, and attention to detail in fitting of the linings.

9.2 Operating practices and time consolidation

The operating practices to be adopted on the plant should if possible be to only fill the hopper when the feeder is running, and certainly to avoid undisturbed residence of material in the hopper for more than a few hours as otherwise blockage will occur. The latter can be achieved by extracting some material at regular intervals. If this precaution is not to be observed, then it will be necessary to have some means of disturbing time-consolidated material in the hopper to initiate flow; vibration is not likely to be successful, but a number of other possible solutions are discussed in section 4 above.

It is also recommended that no material is loaded into the hopper unless the feeder is running, to minimise start-up loads and extend equipment life. Subsequent stopping and restarting of the feeder is likely to be less problematic.

9.3 Trash grid

Any trash grid over the hopper should not have an opening less than 125 mm square, and should be fitted with vibrators to eliminate bridging when this occurs on the grid. The grid should be easily openable to facilitate unblocking of the hopper if this should occur as a result of handling material with excessively bad flow properties, or if excessive time consolidation is allowed to occur.

9.4 Chain-and-flight feeder

The chain and flight feeder under the hopper has been considered and it is estimated that the running chain pull should be around 111 kN (11.1 tonnes force), with a startup chain pull of up to 445 kN (44.5 tonnes force). With a chain speed of 5.1 m/min (based on the lowest material bulk density considered) this equates to 9.5 and 37 kW respectively. Given what is felt to be a more realistic estimate of the actual bulk density, a chain speed of 4.3 m/min is suggested, which should give a feed rate of 150 tonnes/hour ±19%; the power requirements will be in proportion to speed. Electric motor size chosen need not cover the full 37 kW startup power, because of the ability of a three phase motor to cope with overload under such conditions if it is started direct-on-line; the actual choice of motor should be taken up with suppliers. The power supply needs to be very heavily over-rated in order to copy with the DOL starting. The gearbox must be rated to the full 37 kW power, or to take the full locked-rotor torque of the motor actually chosen, if this is greater.

The deck plate material must be stainless steel with either a 2B finish of a "bunker polish finish" (Cromweld reference) with the direction of the finish parallel to the direction of flow. The side plates should be lined with "Tivar-88" UHMW-polyethylene, and should have a slight divergence in the direction of flow.

9.5 Chutes

Chutes for this material should have an absolute minimum angle of 45° to the horizontal, and be lined with "Tivar-88" UHMW-polyethylene. They should have generous fillets in the lower corners and the sidewalls should have some divergence upwards in cross section, as well as a slight increase in width along the direction of flow. These features are illustrated in Appendix C.

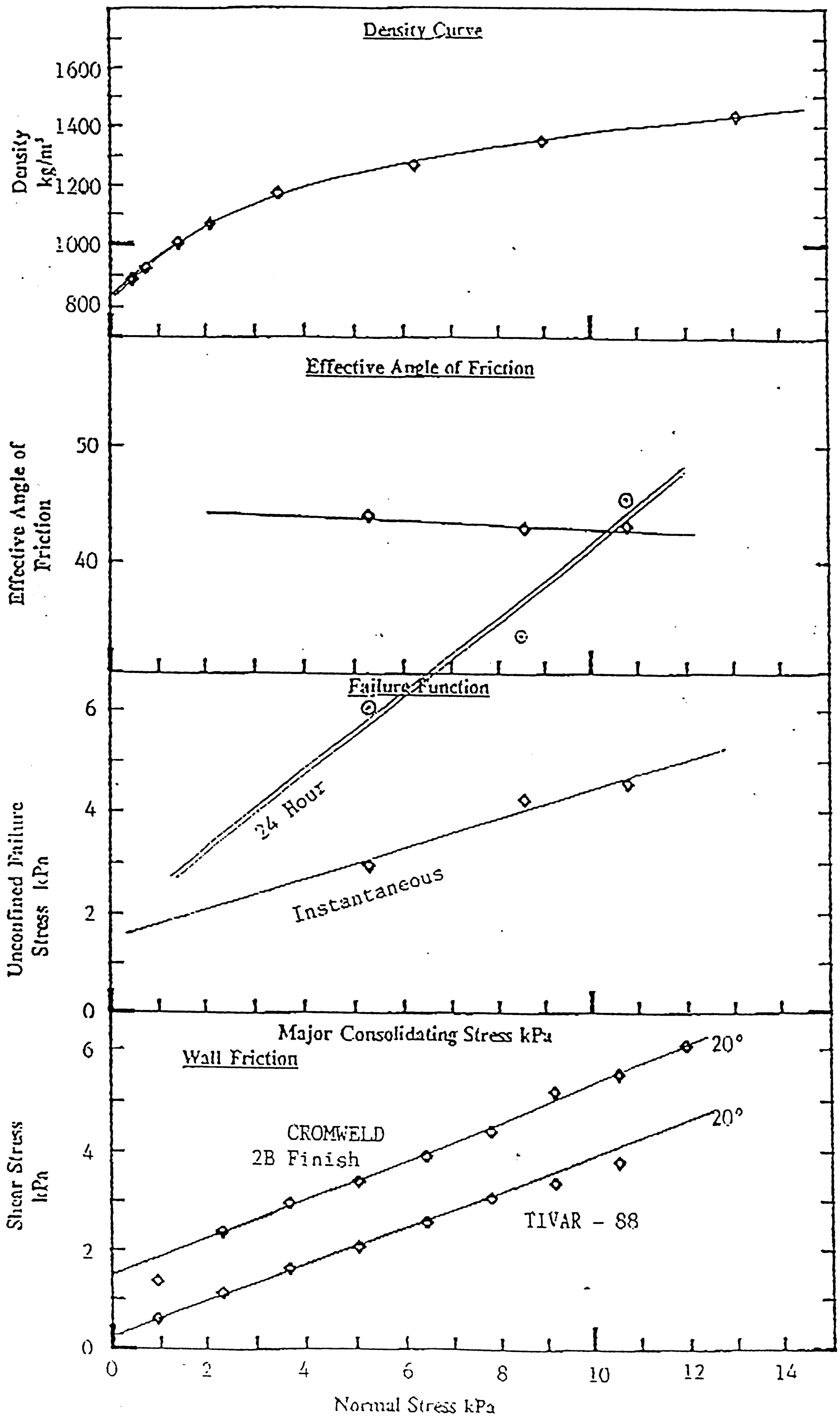
Additionally, the mechanical arrangements of the chutes and the operating procedures in the plant should be such as to avoid material standing still in the chutes, and also to avoid hard impact of material onto the chute, either of which will tend to cause blockages.

9.6 Variation of material

This gypsum will, by its very nature, have a tendency to vary in flow properties, if only as a result of varying moisture content. Consequently a degree of conservatism has been built into the recommendations given above, which were based only upon the material tested. Nevertheless it is inevitable that some stage a batch of material will be arise which will cause problems in handling in this hopper. These problems will probably manifest themselves in one of two ways, either a blockage in the hopper or the stalling of the feeder. It is recommended, therefore, that some contingency plan is held for action under such circumstances. To increase the level of conservatism in the design, it would be necessary to increase the size of the opening at the bottom of the hopper (whilst retaining its geometric shape), possibly in combination with increasing the steepness of the sides, at the same time increasing the width of the conveyor in the same proportion, decreasing its speed but increasing its power.

APPENDIX A

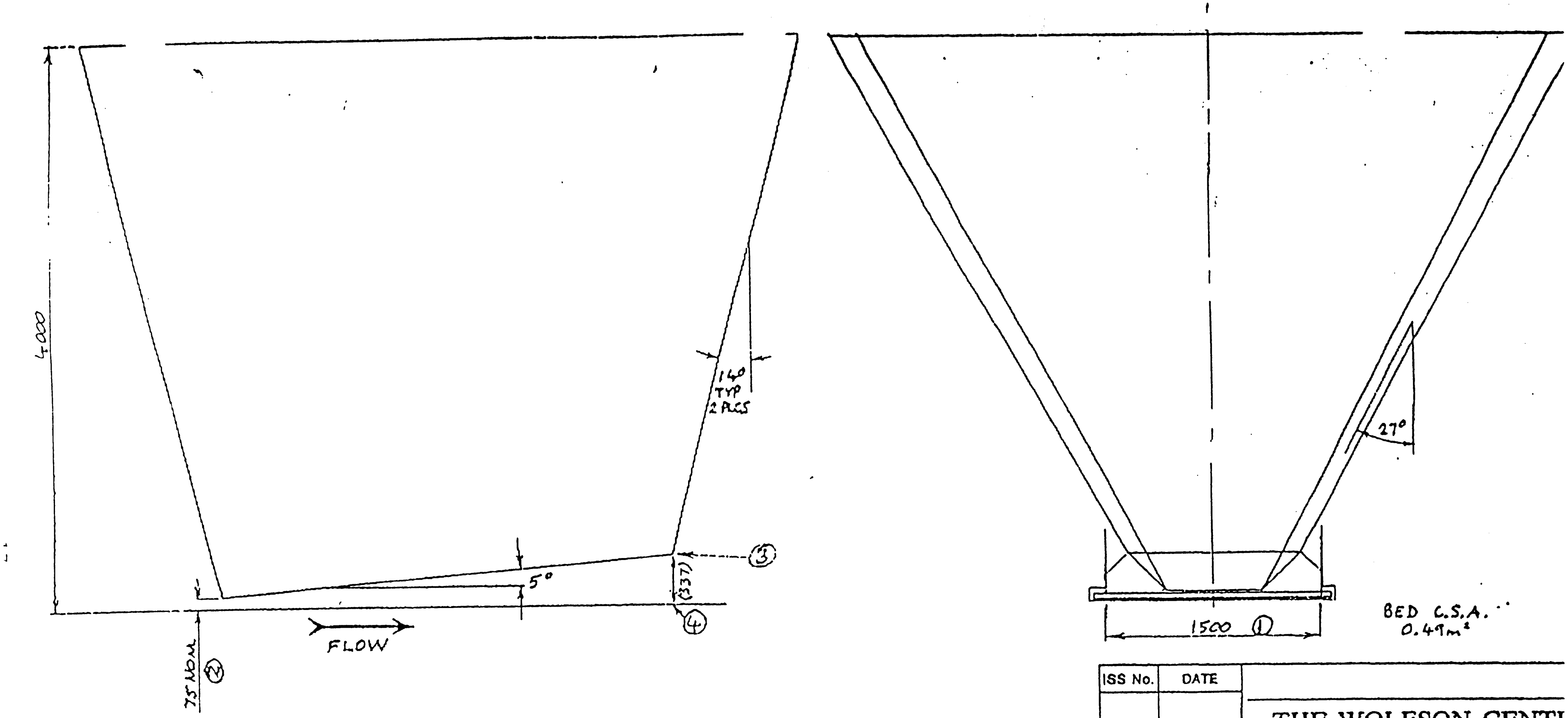
RESULTS FROM TEST WORK



General flow test results from the gypsum tested (6.03% moisture before testing, 5.03% afterwards)

APPENDIX B

Recommended features for incorporation into design of ground hopper



NOTES:

① CONVEYOR NOMINALLY 1500 WIDE BETWEEN SKIRT PLATES, WITH DIVERGENCE OF ½°* IN DIRECTION OF FLOW. WIDTH BETWEEN CHAIN CENTRES CHOSEN TO SUIT. (*-EACH SIDE)

② AS REQUIRED TO CLEAR CONVEYOR FLIGHTS.

③ DO NOT ATTEMPT TO USE A GATE AT THIS POINT TO ADJUST FLOW RATE. SEE REPORT

④ CONVEYOR BED PLATE TO BE 'CROMWELD' · SCRIL WITH EITHER 2B FINISH, OR BUNKER POLISH PARALLEL TO DIRECTION OF FLOW.

ISS No.	DATE
1	27/8/93

THE WOLFSON CENT[RE]
for Bulk Solids Handling Techno[logy]
University of Greenwich,
London, SE18 6PF
Tel: 081-316 8046 Fax: 081-316 8047

TITLE: GROUND HOPPER FEATURES (SCHEME 2): ELEVATIONS.

CLIENT: BRITISH GYPSUM LTD.

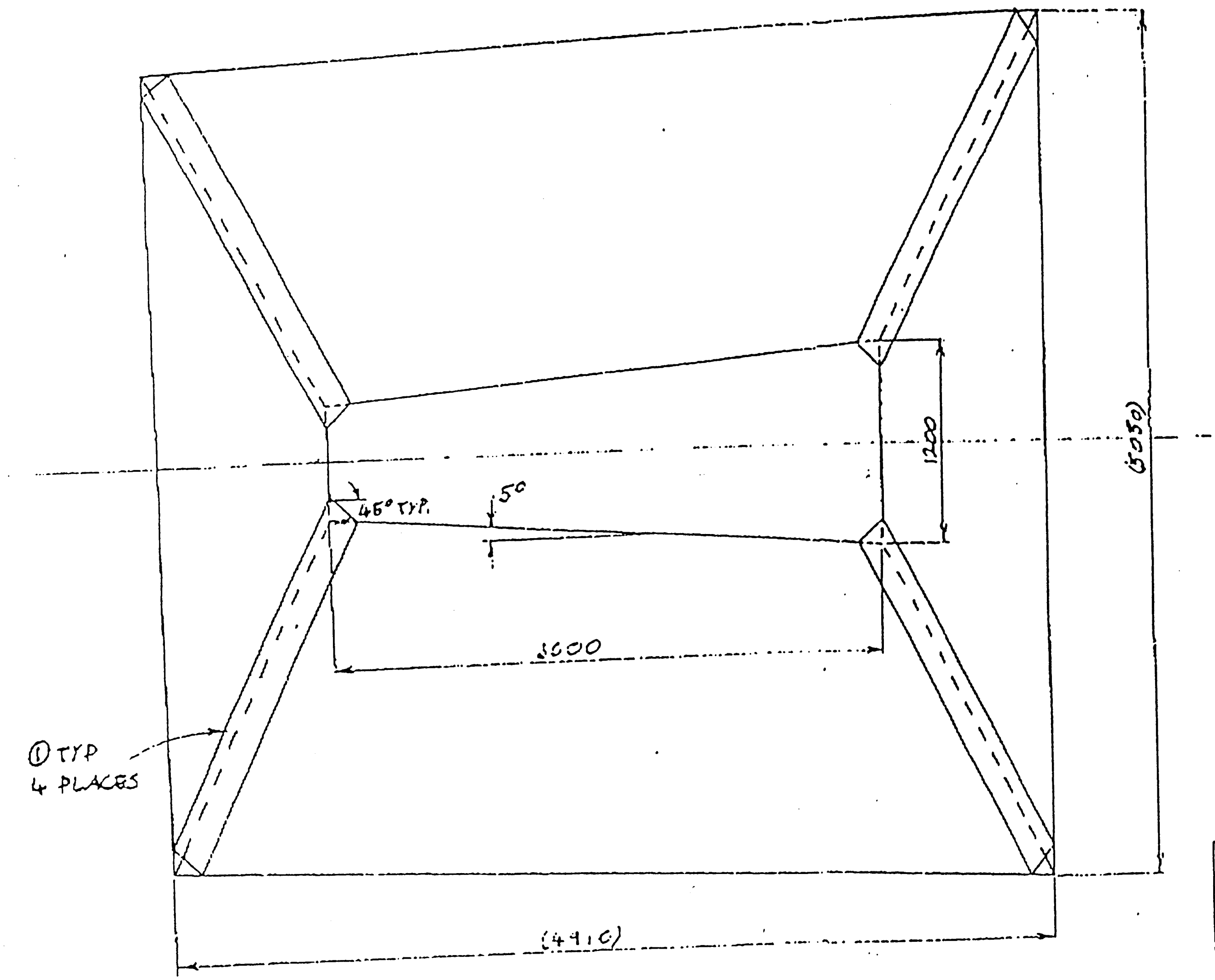
GENERAL TOLERANCES: N/A

DRAWING No.: D/1894/

ORIGINAL SCALE: 1:20

DRAWN BY: M. Bradley

ONS IN: | IF I | JBT | THIRD ANGLE PROJECTION:



NOTES:

① FILLETS 200 WIDE ACROSS INTERNAL VALLEYS

② ALL SLOPING SURFACES TO BE LINED WITH 'TIVAR'-88

③ SLOPING SIDES TO BE FREE OF INTRUSION INTO FLOW SPACE:
(i) ALL BOLT HEADS COUNTERSUNK FLUSH,
(ii) ALL HORIZONTAL JOINTS OF LINING PLATES TO BE SMOOTH.

ISS No.	DATE
1	27/5/93

THE WOLFSON CENTI
for Bulk Solids Handling Technc
University of Greenwich,
London, SE18 6PF
Tel: [illegible] Fax: [illegible]

TITLE: GROUND HOPPER FEAT…
(SCHEME 2): PLAN

CLIENT: BRITISH GYPSUM LTD.

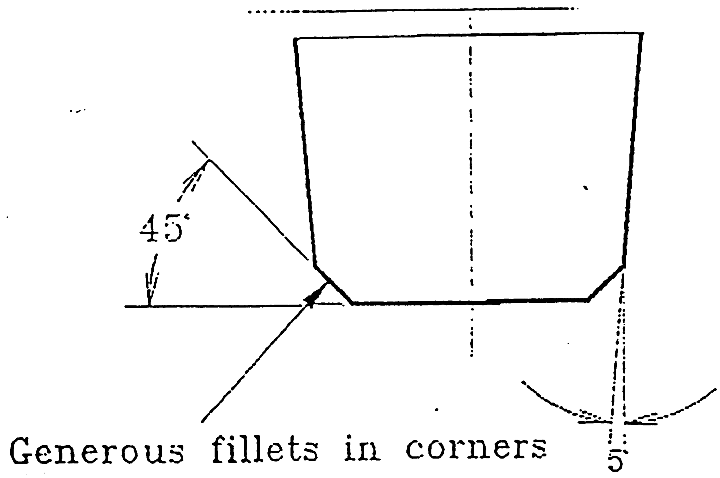
GENERAL TOLERANCES: N/A | DRAWING No.: D/1894/
ORIGINAL SCALE: 1:20 | DRAWN BY: M. Butler

APPENDIX C

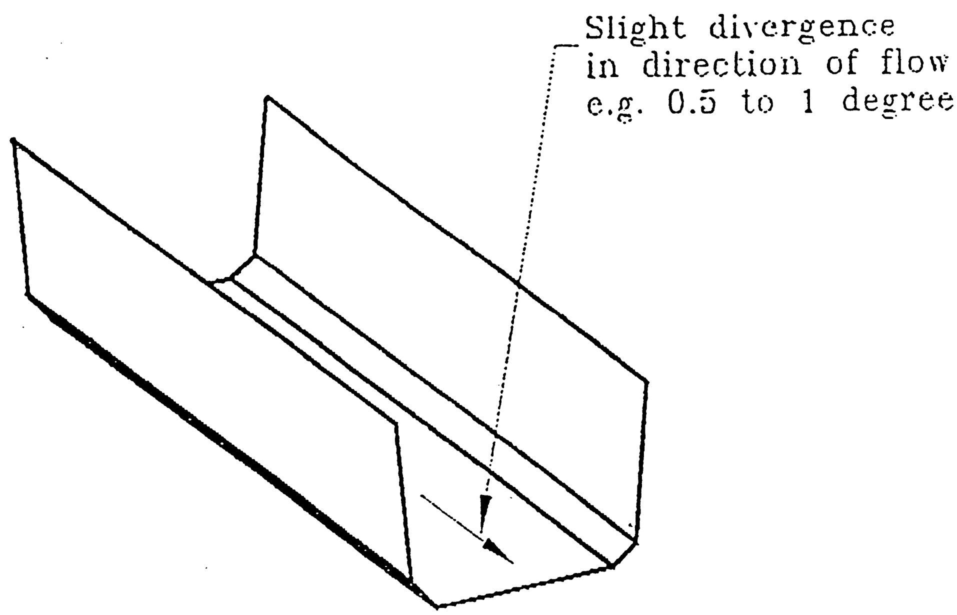
Recommended features for incorporation into design of chutes

APPENDIX D

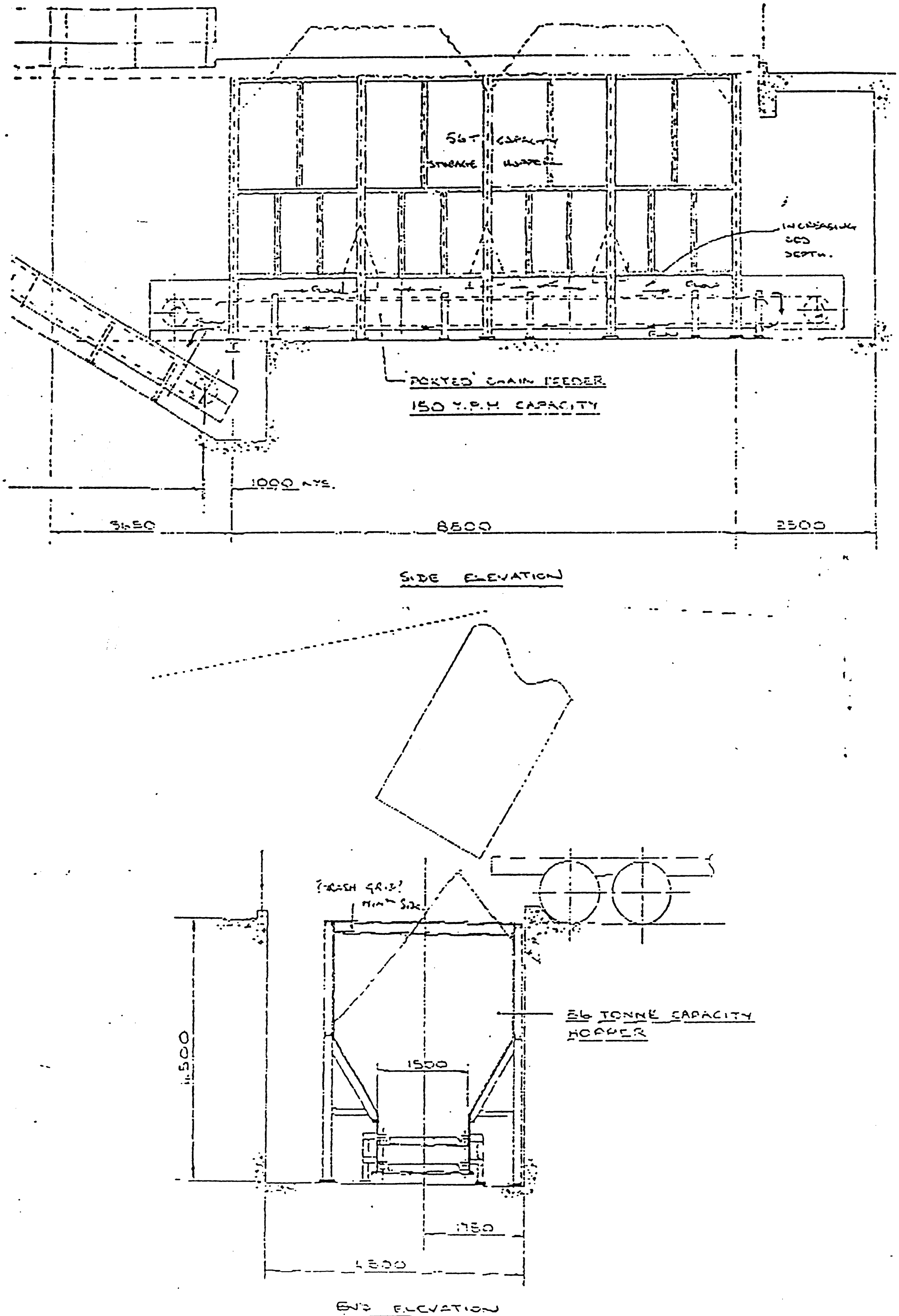
OUTLINE SCHEME PROPOSED BY BRITISH GYPSUM LTD.



Cross section of chute



Recommended features for incorporation into chutes



Outline scheme originally proposed by British Gypsum Ltd.

Report prepared for:-
British Gypsum Ltd.,
East Leake,
Loughborough,
Leicestershire,
LE12 6JQ

by

AH Birks, Consultant

MSA Bradley, Manager

The Wolfson Centre for Bulk Solids Handling Technology,
University of Greenwich,
Wellington Street,
Woolwich,
London SE18 6PF

Tel. 081-316-8646

Fax. 081-316-8647