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B Y

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A B S T R A C T

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Title of Thesis: Separation, Treatment and Disposal of Screenings from Water Pollution Control Works

Little development in screening practice at sewage treatment works has taken place since the basic design was originated some 100 years ago. This thesis details a comprehensive investigation and assessment of screening practice in the United Kingdom. A review has been undertaken of previous work carried out both in this country and abroad and the findings summarised. The results from questionnaires concerning screening practice sent to over one hundred sewage treatment works in this country are summarised and the major problems outlined. During the course of this project visits were made to the main manufacturers of screening equipment and several sewage treatment works and installations to inspect plant and discuss screening practice. The conclusions from these visits are also presented and discussed.

Data relating to screenings quantities and sewage flows has been collected from a number of sewage treatment works, collated and the results analysed.

The various items of equipment available for the separation and treatment of screenings have been evaluated, their advantages and disadvantages discussed and recommendations made on their operation and application. The various methods of disposal have been evaluated and recommendations made.

The feasibility of constructing a pilot plant to test screenings equipment has been investigated and recommendations are presented.

Finally, recommendations have been made concerning screen design and screening practice, and the necessity for further work in some particular areas.

A C K N O W L E D G E M E N T S

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Grateful thanks are also due to the managers, controllers and supervisors of the sewage works and installations visited, listed in Section 3.2, for their co-operation and to the personnel of the regional water authorities and regional councils who completed the questionnaire and provided operating data.

Acknowledgement is made to all equipment manufacturers who willingly supplied information on their products, in particular those listed in Section 3.2

Finally, thanks are also due to the Construction Industry Research and Information Association who funded this research project and to my employers, Balfours, without whose co-operation and help this project could not have been completed.

A B B R E V I A T I O N S

The following abbreviations have been used in this thesis:-

BOD	biochemical oxygen demand
BSC	British Steel Corporation
CIRIA	Construction Industry Research and Information Association
COD	chemical oxygen demand
DWF	dry weather flow
IWPC	Institute of Water Pollution Control
NWA	Northumbrian Water Authority
STW	sewage treatment works
SS	suspended solids
UK	United Kingdom
USA	United States of America
WPCF	Water Pollution Control Federation
YWA	Yorkshire Water Authority

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1. INTRODUCTION

1.1 GENERAL

Crude sewage contains mineral and organic matter in many forms including: large and small solid material floating and in suspension; substances in true solution; and finely divided 'colloidal' matter. The large or gross solid material consists of rags, paper, wood, fibres, plastics, faecal matter and other debris which because of their size, can cause blockages and/or damage to pipework, pumps, valves and equipment at treatment works. The preliminary stage in the treatment of sewage is thus aimed at minimising these difficulties in order to protect the main processes which follow.

The method widely used for overcoming the problem of these solids is to pass sewage through screens - a process known as 'screening', where much of the material is intercepted (i.e. separated) and removed either for disposal or for return to the sewage flow after reducing the size of the intercepted material - 'the screenings'.

Screenings invariably have a foul odour and objectionable appearance due to the associated faecal material, and have a high water content of around 75 to 90%. The traditional methods are removal and burial or their removal and maceration followed by return to the sewage flow. With this latter method, there is often a tendency for the disintegrated fibrous matter to reform into strings, or 'ball-up' giving rise to certain problems in pipework and the subsequent treatment units. Incineration of screenings is rarely practiced in the United Kingdom (U.K.), while the recently introduced methods of dewatering screenings by pressing are mainly of foreign design.

1.2 REASON FOR SUBJECT

Little development in screening practice has taken place since the basic design was originated some 100 years ago. This is possibly due to the fact that the process is not strictly a stage of treatment for sewage and it is relatively cheap, simple and mechanically reliable. The increase of labour costs and the difficulty in obtaining personnel to carry out unpleasant tasks has meant the replacement of a traditionally manual operation by automated and standardised plant, and highlighted the need for a critical investigation in this area. A report[1] stated high priority should be given to research aimed at reducing or eliminating the considerable sources of nuisance resulting from existing techniques.

Also, preliminary investigation showed that most work in this field had been carried out by manufacturers and there was a need for comparison of operational methods.

1.3 AIMS

The aims of this research project are the investigation of the methods and associated problems of the removal (screening) and disposal of gross solids (screenings) which arise as a result of preparing sewage at the entrance to a Sewage Treatment Works for subsequent treatment in downstream units.

1.4 PLAN OF WORK

The original plan of work for this project was as follows:

(i) The study and analysis of past papers and research
(ii) The study of the problems associated with screening and screenings disposal at Sewage Treatment Works in the United Kingdom
(iii) The collection and collation of data relating to the separation, treatment and disposal of sewage screenings from selected Sewage Treatment Works
(iv) The development of improved data collection methods, and the provision of a network of data collection points at designated Sewage Treatment Works
(v) The interpretation of new data
(vi) The investigation of the feasibility of constructing a pilot plant to test screenings equipment

1.5 METHODS OF WORKING

1.5.1 Literature Review

The initial literature search was undertaken in the libraries of the Universities of Sheffield and Newcastle-upon-Tyne, Sheffield Polytechnic, B.S.C. Rotherham and the City of Sheffield.

It was decided to adopt a computer file management system and to store all information collected during the course of the project on the Sheffield Polytechnic computer. A program needed to be developed to meet the needs of the project and to do this the Mark IV file management system marketed by Informatics Incorporated, California, U.S.A., was used (Appendix B).

1.5.2 Survey and Visits

The survey was carried out initially by means of a carefully worded questionnaire sent to a select list of Sewage Treatment Works throughout the country. The questionnaires were followed where necessary by requests for further information and by visits to selected Works to collect data and discuss with Managers and other personnel methods and associated problems. Visits were also made to the main manufacturers of screening equipment.

2. LITERATURE SURVEY

2.1 INTRODUCTION

An extensive literature search was carried out using the following standard works of reference:-

Engineering Index (1979 to 1896)(American)
British Technology Index (1979 to 1962)
Water Research Council Information (1979 to 1973)
Water Pollution Abstracts (1973 to 1928)
Public Health Engineering Abstracts (1967 to 1954)

The amount of published information was large - some 650 references in all - a high proportion eminating from North America, with the majority written before World War II and coming from the period when screening of sewage was a more important aspect of sewage treatment than it is today, being either the only treatment given or at least still considered a viable alternative to sedimentation. With the increase in the use of sedimentation and biological treatment of sewage the interest in screening has declined and little has been written regarding modern practice or experience.

After careful consideration of the synopses given in the standard works, copies were obtained of over 200 papers and publications. All of these were read and about 190 were filed for detailed consideration when compiling this review. Not all references examined in detail have been incorporated into the review, instead, an attempt has been made to include all topics of relevance to the subject and to mention briefly the main research studies and operation experience that have been reported in past years.

2.2 CHARACTERISTICS AND QUANTITY OF SCREENINGS

2.2.1 Characteristics

It is not feasible to present quantitive data on the nature of screenings for general application since their origins can be very different. Indeed it has been pointed out that the nature of screenings varies from community to community, as well as in the same city from season to season[2]. Screenings are usually offensive in nature and may include almost any conceivable object in addition to the solids normally present in domestic sewage.

There is a general lack of data concerning the nature and composition of screenings in the U.K. but some data available from studies carried out in the United States of America (U.S.A.) in the 1930's Moisture content of screenings has been reported by most authors to be between 75 and 95% by weight. Copeland[3] found that organic solids removed from screens consisted of 40% fats and oils, 10% cellulose (mainly paper), 35% proteins and 15% minerals and water. Rudolfs and Heisig[4] reported a fat content of 19.3% for screenings from fine screens (screens of openings less than 10mm) in Milwaukee.

Volatile matter contents of screenings of 80 to 90% from coarse screens[5,6] and 68 to 93% from fine screens[7] have been observed. Investigations by Gascoigne[8] involving the incineration of screenings gave a calorific value for fine screenings, the dry solids of which contained 91% volatile matter of 19 MJ/kg. In the U.K. recently calorific values between 17 and 21 MJ/kg[9,10] have been proposed. A value of 2 MJ/kg was reported by Sperry[11] for drained screenings (80% moisture content) at the Aurora III sewage treatment works in Illinois.

Studies[12] have revealed that distillation of one tonne of screenings of 85% moisture content yielded about 23m^3 of gas (calorific value 420 kJ/m^3), 45 kg of fuel oil and 68 kg of fertiliser base.

In their recent publication[13] 'Preliminary Processes' (of sewage treatment), the Institute of Water Pollution Control quoted the following to be typical of the characteristics of screenings from domestic sewage in the U.K.:

1. density between 600 and 1000 kg/m^3
2. moisture content between 75 and 90%
3. volatile matter content of the dried solids between 80 and 90%

The above data may be regarded as typical of the characteristics of screenings from domestic sewages containing only low proportions of trade effluents. They are however, inapplicable for sewages containing high proportions of trade effluents liable to give rise to high or low screenings volumes or for trade effluents alone.

2.2.2 Quantity

American work has shown a wide range in the quantity of screenings and clearly the amount depends, inter alia, on the size of the screen openings. Also Muddoon[5] has pointed out that quantity depends on a number of additional factors viz:- whether the sewers are separate or combined, whether or not the sewage is pumped and the distance the sewage flows through the system before reaching the screens. Keefer[14] considered that in addition to the size of openings the other chief factor affecting volume was the velocity through the screen. Besselievre[15] reported that the quantity of screenings doubled when screens were changed from hand raked to mechanically raked.

Some results of the volumes of screenings collected related to screen openings are presented in Table 2.1, indicating volumes of about 15 litres/1000m^3 of sewage with openings of 25mm to in excess of 150 litres/1000m^3 with openings of 1.5mm and less. Unfortunately, no comparable information appears to be available for U.K. conditions, although the yields which have been reported for a few sewage works in the U.K., (Table 2.1) are not inconsistent with the corresponding American data. In South Africa Lundie[16] found that the amount of screenings was high due to the night soil content; the annual average volume of screenings from 13mm spaced bar screens was 436 to 498 litres/1000m^3. In 1948 a Civil Engineer's Review[17] reported that weak domestic sewage passing through screens of 25mm openings produced 6 litres/1000m^3 in dry weather and up to 75 litres/1000m^3 in times of storm.

It has been reported[18] that the average amount of screenings from military installations was found to be 20 litres/1000m^3 for screens within the range 19mm to 38mm with a spread of 5 litres to 56 litres/1000m^3, the high quantity being attributable to the freshness of military sewage.

Gasgoigne[8] has observed that daily quantities of screenings ranged from a minimum of 20 per cent to a maximum of 400 per cent of the average and it has also been reported based on findings from 117 plants that the usual maximum peaks are 200% of the average quantity although they are sometimes ranged as high at 500%.

Table 2:1 Relationship of Screen Opening to Volume of Screenings (Volumes in litres/1000 m^3 of sewage)

Country of origin	Screen size clear opening (mm)									Reference
	51	38	25	19	13	6	3	1.5	0.8 to 1.5	
U.S.A.			13		24	37	60	179		22
U.S.A.			15	22	37			150		8 (a)
U.S.A.	7		23		64					23 (b)
U.S.A.									150 to 224	5
U.S.A.			12 16							24
U.K.			6							17
U.K.			19							25
U.K.	10									26
U.S.A.			14							27
U.S.A.				9						2
U.S.A.				6						28
U.S.A.					37					7
U.S.A.	11									29
S.A.			31					249		16
U.S.A.		11		37						30
U.S.A.	6									15
U.S.A.								210		31
U.S.A.	3						32			32
U.S.A.		3			36					33
U.S.A.	3		25		69		124			34

(a) Average values, actual volumes fluctuated from 20 to 400% of average

(b) Values based on findings from 117 different plants

The quantity of screenings is to some extent related to head of population served but unfortunately the foregoing figures give quantities in proportion to flow without stating the consumption. The following figures based on population are given by Escritt and Rich[19],

Screen Size	Volume (m^3/1000 pop/day)
12mm	0.023
19mm	0.014
25mm	0.008

Fair and Geyer[20] give 0.015 and 0.008m^3/1000 pop/day for 12mm and 25mm screens respectively, whereas the I.W.P.C. in their recent publication[13] quote typical figures of 0.01 to 0.03m^3/1000 pop/day.

Keefer[14] produced a graph (Fig. 2.1) based on observations at Long Beach U.S.A. that showed the hourly variation in quantity of screenings was directly proportional to the flow, a fact confirmed recently by Roebuck[21] in the U.K. (Fig. 2.2). Figures for the amount of screenings at peak flows have been given and are reproduced in Fig. 2.3.

Stilson[22] stated that it is impossible to give exact figures as to the production of screenings and it is considered by Hendryx and Carrington[14] based on observations made at a single location over a period of two years, that screenings volumes are difficult to predict with any accuracy. Due to the large reported variations in the nature and quantities of screenings there is no evidence to suggest that there have been any increases in the quantities of screenings over the years. Also evidence does not suggest that there are any appreciable differences between screenings derived from sewage in the U.K. and the U.S.A.

2.3 TRENDS

Future trends in screening practice and the nature and quantity of screenings are difficult to predict from existing information. Ainsworth[36] discusses likely future problems and notes that as the standard of living rises, so do the quantities and complexities of urban and industrial wastes. He gives examples to illustrate the growing tendancy for anyone with a tricky disposal

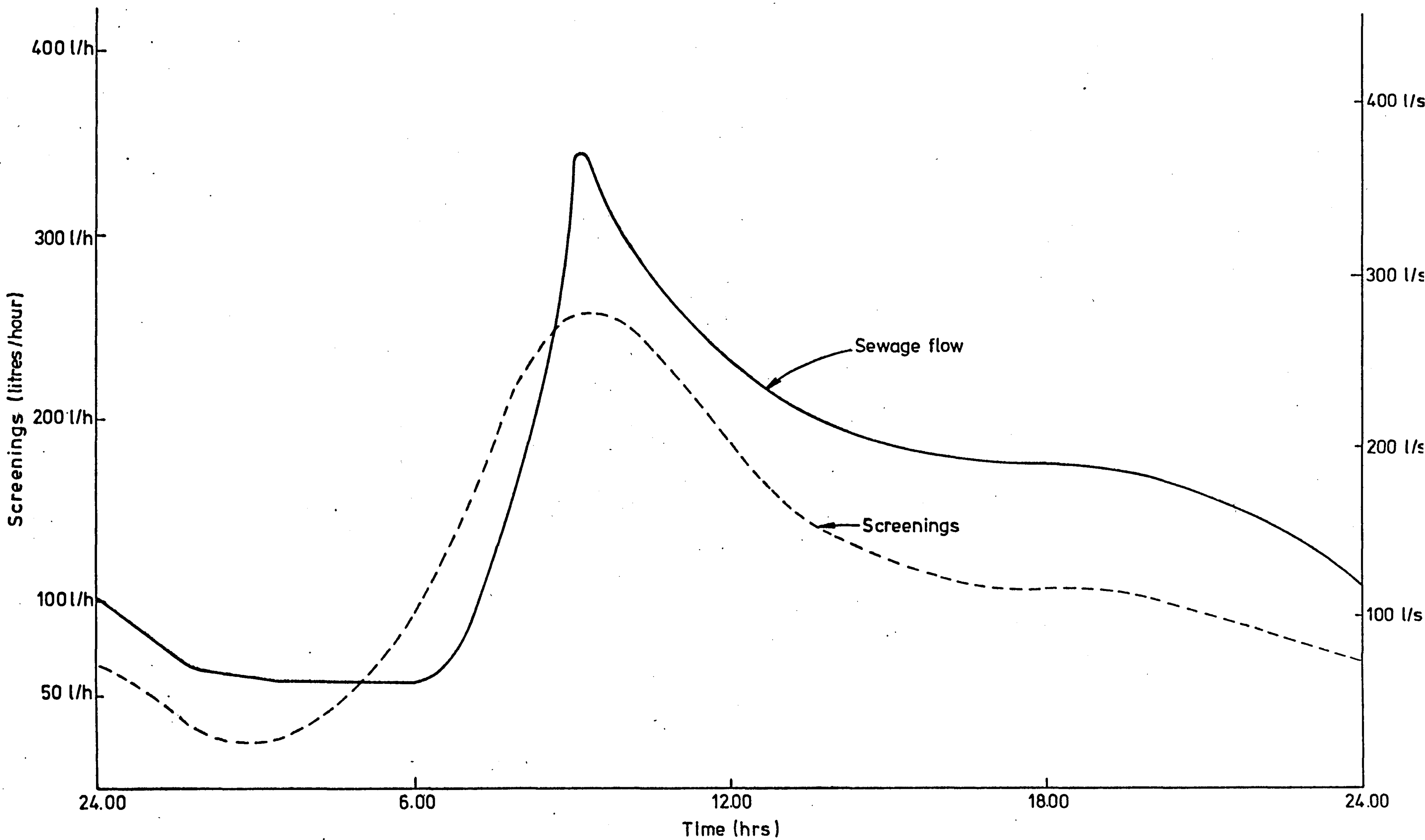


FIG. 2.1. Hourly quantity of screenings removed from fine screen, Long Beach U.S.A.

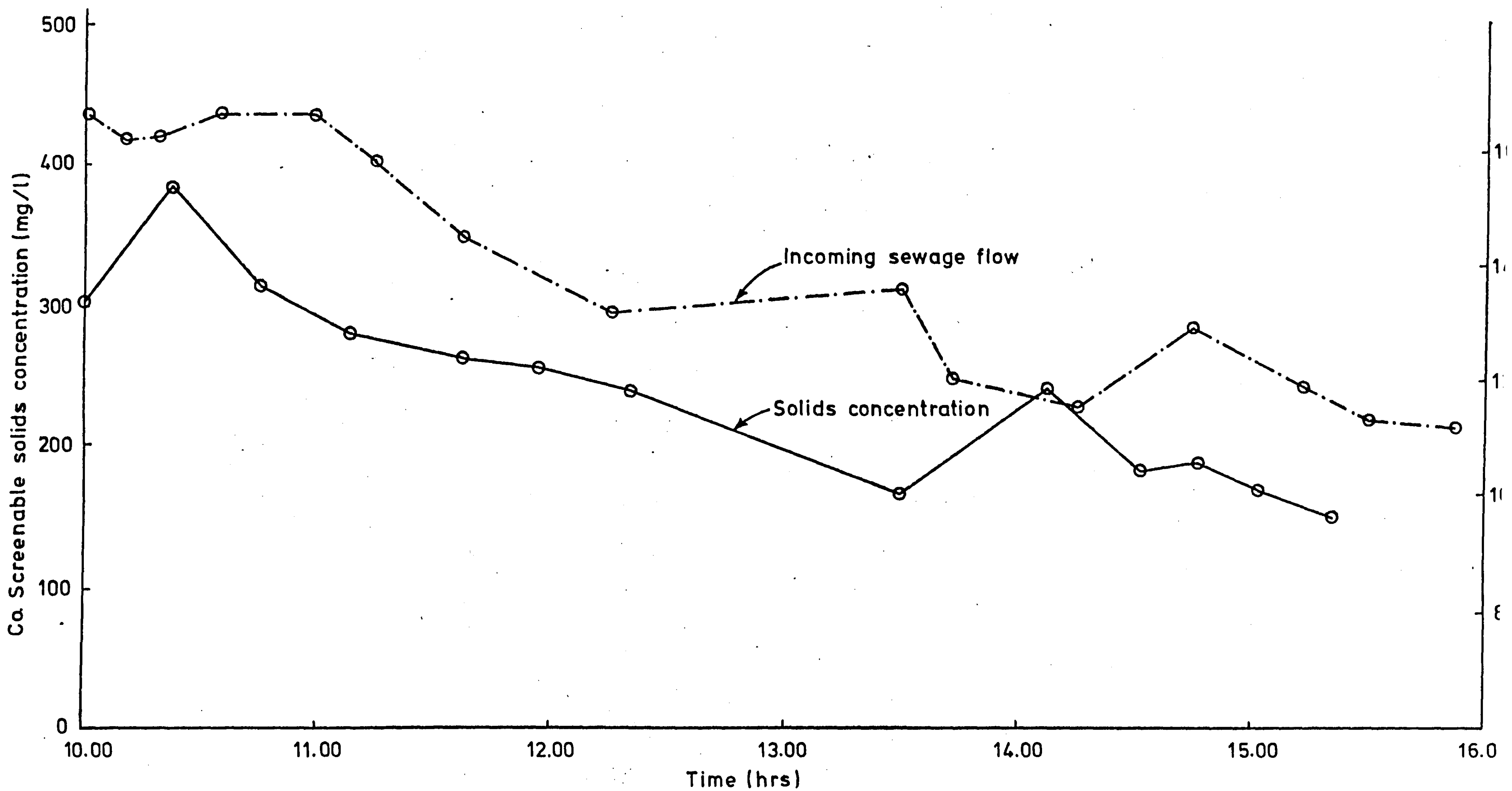


FIG. 2.2. Incoming sewage flow and screenable solids concentration v time.

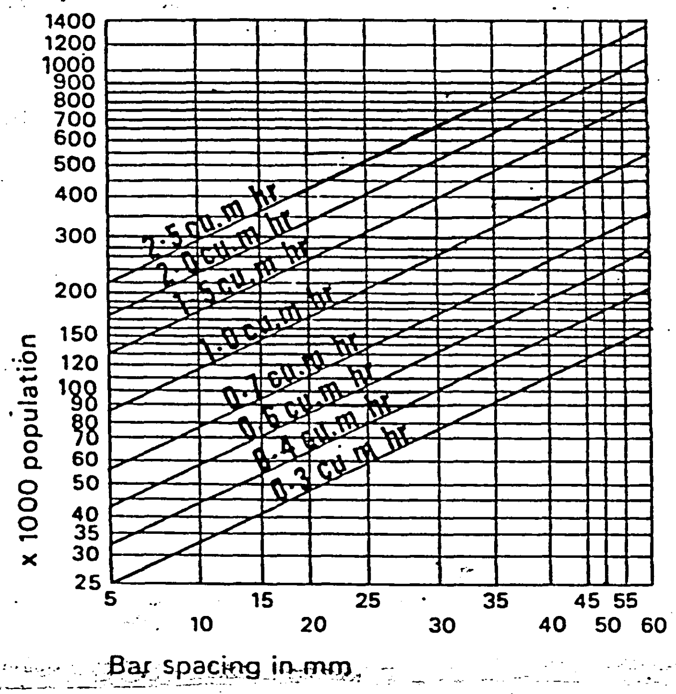


Fig. 2.3 Relationship between Screen Openings and Volume of Screenings at Peak Flow (13).

problem to seek a convenient solution by putting it 'down the drain'. In discussions, he further considers that with the increasing use of sewers for unwanted and objectionable material, problems could arise with screenings disposal, particularly on large works, and that it is time to have a fresh look at the preliminary treatment processes, to see if, in fact, conventional methods would be appropriate when greater quantities of intractible coarse solids are passed into the sewers.

Ainsworth also predicts an increase in the use of domestic garbage grinders which would increase the non-biodegradable load on sewage works. Although their increased use would have little effect on coarse screenings, the amounts and characteristics of fine screenings could be altered considerably.

The increasing tendency to use plastics and synthetic materials will also increase the non-biodegradable load on sewage works; indeed Staudinger[37] forecast a five fold increase in the weight of plastics in refuse in the U.K. over the period 1970 to 1980. It is likely that screenings will follow the same trend.

2.4 SEPARATION PRACTICE

2.4.1 General

Crude sewage contains gross solids which are either organic or inorganic in nature and of such a size that, if not removed, they can create difficulties in the subsequent treatment plant. To minimise difficulties caused by their size they may be[12]:

(a) removed entirely

(b) removed and returned to the sewage flow after their size has been reduced, or

(c) reduced in size without removal from the sewage flow.

Screens which were among the first modern devices used in attempts to remove deliterious material for sewage and the following objects are accomplished, at least in part by screening[23]

(a) protection of pumps, pipes, syphons, valves and penstocks

(b) removal of floating matter that tends to form unsightly scum on settling and aeration tanks

(c) removal of solids which would tend to clog or otherwise interfere with mechanical sludge-moving equipment

(d) prevention of heavy and extremely tough floating scum on the surface of sludge digestion tanks

(e) removal of solids likely to clog filter nozzles

(f) removal of larger solids that may settle to the bottom of aeration units

(g) removal of coarse solids not penetrated readily by chlorine when sewage is disinfected

(h) as a temporary expediant while developing more complete methods of treatment

However, opinions [13] are divided not only about the type and size of screens to be used but also over the advisability of screenings at all. The alternative practice of using comminutors or barminutors does not require the removal of screenings from the flow and the unpleasant disposal task is avoided. There are, however, associated problems and the use of screens can be advantageous.

The maximum size of the openings in any screen is dependent upon the size of the largest particle which may be allowed to pass. Various guide lines for the choise of openings have been suggested [13,19,38] as follows:-

Location	Minimum dimension across opening (mm)
Protection of Sewage Pumps	50 to 150
Inlet Works	10 to 50 (20 norm. U.K.)

For the purpose of this thesis the following screen classifications have been adopted:-

Screen	Minimum dimension across opening (mm)
Coarse screen (hand and mechanical)	> 10
Fine Screen	$\leqslant 10$
Special Screen	N/A

Fine screens were in common use for the removal of gross and fine solids from sewage until about the beginning of the 20th century when primary sedimentation was developed and subsequently became widely accepted for fine solids removal. Fine screens are now used in the U.K. almost exclusively at sea outfalls although they have found wider application in the U.S.A. and on the Continent. Due to the lower efficiency of fine screens[39] the economics of fine screening generally compare unfavourably with primary sedimentation although Halvorson and Smith[41] considered that the costs were comparable. In the U.S.A. Lager and Smith[42] have considered various types of fine screen and assessed the relative efficiencies, screen lives, ease of cleaning, design parameters and costs. However, they made no particular conclusions or recommendations.

As previously noted one of the main reasons for the inclusion of screens at a sewage works is to protect the various mechanical installations. Hurley[43] took the view that the sludge pumping plant is in the main feature to be protected and hence recommended only a coarse screen at the works inlet and fine screening for the sludge. The result, he argued, would be a reduction in the amount of screenings, protection of the sludge pumps, and a sludge of higher fertiliser value. Conversely fine screens have been installed to avoid the necessity for sludge screening or maceration prior to sludge pressing[44].

2.4.2 Hand Raked Screens

Hand raked screens were amongst the first methods of removing solids from sewage, initially used mainly to protect pumps, their development from the early gratings and sieves has been detailed by Stanbridge[45] and Dunbar and Calvert[46]. The earliest types of screen were perforated wooden plates, first reported in 1853, with the first mention of an iron grating being in 1864. These early screens were placed at various angles in the flow, even horizontal. They were also placed on hinges, like doors, in the sewers and perforated baskets were also used. These screens were either cleaned within the flow with rakes or as in the case of cage screens[14,45] were removed from the flow for cleaning.

Mechanical screenings plant has mostly superceded hand raked screens, and now apart from very coarse screens (100mm to 150mm openings) placed upstream of mechanical screens to prevent damage from large objects[13] hand raked screens are only recommended[13,47] for use on very small treatment works, small pumping stations and in by-pass channels on larger treatment works. Though the tendancy from them to be superceded by mechanical plant even on very small treatment works has been noted[47]. It has also been suggested that at very small works screens are more of a nuisance than a help and instead scum boards should be used purely to arrest floaters. In a recent publication the I.W.P.C.[13] consider that the use of hand raked screens should be restricted to works treating less than 1000m^3/day whereas in the early fifties Caster[48] was recommending their use on works treating flows from populations up to 10 000. Lang[49] recommended that if the incoming sewer is small (150mm to 225mm diameter) then the hand raked screen which would normally be installed for such a small works should be omitted. He suggested that in order to provide sufficient area of screen for narrow channels a 'two-slope' bar could be used. This has a bottom section of low inclination and a top section of steep inclination.

Opinions differ regarding both bar spacing and slope. On the question of spacing recommendations vary from 15mm to 50mm with a concensus of opinion favouring 25mm. Scott[50] suggested that the spacing should match that of the common garden rake as this, regardless of the rake originally supplied, was the impliment the operator ended up with. With regard to slope the I.W.P.C.[13] recommended an angle of 60° to the horizontal whilst in the U.S.A. the W.P.C.F.[38] stated that the most common angle of existing hand raked screens was 60° though the present tendancy was to use a slope of 30° with a maximum of 45° usually accepted. It is pointed out[35,57] that a flatter slope makes cleaning easier, and further that the action of the flow will push the screenings up the bars rather than cause a blockage. Round bars are being used though it is recommended that[13] screen bars should be designed with the leading edge slightly wider than the trailing edge to minimise the jamming of the large solids between the bars.

A drainage platform should be provided for fresh screenings[52] preferably extending[48] over the edge of the screening chamber to facilitate loading of skips.

Problems of deposition of grit within the screenings chamber are mentioned by I.W.P.C.[13] who recommend that the velocity through the bars should not drop below 0.3m/sec to prevent this deposition, at least 0.45m/sec should be reached under normal flow conditions and the maximum velocity should not exceed 0.9m/sec or screenings which have already been intercepted may be dislodged. Other design figures suggested[47,52] are an approach velocity of 0.3m/sec to 0.6m/sec or a velocity through the chamber of 0.4m/sec to 0.8m/sec. Various empirical design figures have been suggested for very small works; a maximum area irrespective of flow of $0.7m^2$ [53], area of twice the area of the incoming sewer[54], $0.14m^2$ of submerged area per 1000 population[13] and $0.58m^2/1000m^3/d$. These areas assume frequent cleaning of the screen and in the latter case a maximum of 3 times during the day is suggested with the screen left clean at night. Merz[35] states that it is particularly important that a definite routine is established for the normal cleaning of screens because it is not a very desirable job and if neglected can effect the operation of the treatment works. To reduce the amount of soft organic solids included in the screenings, the solids accumulated on the screen may be rolled with a light roller prior to raking so that the soft organic solids are squeezed through the bars[52].

2.4.3 Mechanically Raked Screens

As with hand raked screens, the development of mechanical screens in the U.K. from 1865 has been detailed by Stanbridge[45]. Screening is usually the first process at a sewage treatment works, but some operators and designers such as Townend[55] have argued that damage to mechanical screens by grit is best prevented by providing a grit removal device upstream of the screens. Hurley[43] pointed out that grit channels located before screens helped to reduce the problem of screen jamming, primarily because the grit channels reduced the flow velocity. A Civil Engineering Report[56] referred to the sewage treatment works at Budds Farm, where the screen chambers were located downstream of the grit channels. The horizontal screens (19mm openings between bars 9.5mm wide) were placed over hopper bottomed tanks. All the sewage entering the chambers rose through the screen and the screenings remained in the tanks until they were discharged to a mechanical screenings washer. No operating data were presented. These screens were replaced by comminutors in the late 60's. However, modern automatic grit removal systems are adversely affected by large solids, rags, etc., and hence the current tendency is for screening to precede grit removal.

Conventional British design of coarse screens has been outlined by Moore[57]. He considers that the choice of bar opening must achieve the cleanest possible screenings consistent with sufficient removal of solids to protect the downstream mechanical installations and that unless pumps have large freeways, it is undesirable to have screen openings of greater than 25mm. He suggested tapered bars 64mm deep, 13mm wide at the front and 6mm wide at the back, inclined at 60^{o} to the horizontal and that the raking mechanisms for screenings removal should operate by a float, activated when the upstream depth reaches a certain level. Details of different methods of screen operation are given by Escritt and Rich[44].

The Institute of Water Pollution Control[13] considered that, with pump sizes of more than 150mm, screening is often not necessary and with smaller pumps a coarse screen with openings of 75 to 150mm is required; when comminution is being carried out, a screen with openings between 75 and 100mm should precede the comminutor, and if 'balling up' is likely to occur a screen with 12.5mm openings should follow the comminutor. To prevent grit being deposited on the screens it was recommended that the sewage velocity between the bars be at least 0.45m/s, but not more than 0.9m/s to avoid jamming. Winsor[27] found that 76mm openings allowed the passage of too many large rags, causing subsequent blockage of sludge pumps. A 51mm screen was found to reduce pump blockages to a low level.

These design criteria differ slightly from past North American practice. A Canadian Municipal Utilities Report[58] of 1952 recommended that bar screens should precede mechanically cleaned grit chambers; bar openings should be 16mm; the average velocity in the screen chamber should be at least 0.3m/s and not greater than 0.76m/s.

Merz[35] considered 25mm bar openings to be quite satisfactory and found that this opening was used on 42% of works surveyed. He further considered bar openings of 12mm to be the minimum practical from a hydraulic standpoint with the ideal angle for a screen being 60^{o} to the horizontal; over 75^{o} operating difficulties could be anticipated. Control of mechanical screens should be by time switch with an over-riding emergency float switch.

Federick[53] in 1952 suggested the following formulae for calculation of head loss through bar screens:

$$h_L = \frac{V^2 - v^2}{2g} \times \frac{1}{0.7}$$ where h_L = head loss (m)

or $$h_L = \frac{0.5v^2}{2g} + \frac{V^2 - v^2}{2g}$$

V = velocity between bars (m/s)

v = velocity in approach channel (m/s^2)

g = acceleration due to gravity (m/s^2)

Kirschmer[59] gave the following formula for the calculation of head loss:

$$h_L = \beta \left(\frac{s}{b}\right)^{4/3} \frac{v^2}{2g} \sin \theta$$

where s = thickness of bars (mm)

b = width of space between bars (mm)

v = velocity in approach channel (m/sec)

β = a function independent of s/b, but dependent on cross section of bar.

θ = angle of the screen to the horizontal

Values of B are as follows:

Bar type	β
Rectangular cross section	2.42
Flat bar with rounded 'nose'	1.83
Circular cross section	1.79
Streamlined cross section	1.67 to 0.76

Tolman[60] recommended mechanically cleaned screens since smaller concrete structures are required and the more frequent cleaning results in little loss of head. He regarded the back raked screen as very dependable since it is very difficult to jam the rakes. For large plants treating greater than 0.13 M m^3/d he stated that it was common practice to use two screens, the first with 50 to 100mm bar openings, and the second with 19 to 25mm bar openings; and he recommended a velocity of flow through the bars of about 1.0 to 1.2m/s.

Gail[61] has presented an interesting innovation on coarse screen design. His new type of coarse screen consisted of a number of parallel, vertical, zig-zag sheets placed in the flow channel. He drew attention to the limitation of conventional coarse screens in that they catch rags, paper and other fibres, which need not be removed at the screening stage since they would be removed in primary sedimentation tanks. The zig-zag screen would intercept large objects but allow the passage of rags and paper. Much less cleaning was found to be necessary than with conventional bar screens.

A recent paper by Galiza[62] mentioned the dangers of enclosed screen chambers, particularly in industrial situations due to the possibility of explosive and corrosive gasses and liquids present in the waste flow accumulating in the screen chamber. He discussed electrically operated screens with particular emphasis on safety factors under such conditions.

2.4.4 Fine Screens

2.4.4.1 Types of Screens

Allen[63] of the USA was one of the first authors to outline the different types of fine screen. He distinguished five main types to which most later designs may be related.

1. Band Screen - the screen is in the form of a continuous belt or band;
2. Wing Screen - consists of a central shaft to which are attached several flat screens shaped like wings. One of the wings is always in the sewage flow;
3. Shovel Vane Screen - similar to the wing screen but has curved screens in place of flat ones;
4. Drum Screen - the screen is in the form of a rotating cylinder of wire mesh or similar, the screened sewage passing into the cylinder leaving the screenings on the outside;

5. Reinsch-Wurl Screen (disc screen) - the screen is in the shape of a hat or disc which rotates and is tilted into the sewage flow at one side.

A modification of the drum screen is the 'Weand' or 'Cup' screen in which the sewage enters a cylinder at one end with the screened sewage flowing radially out of the drum leaving the screenings inside.

2.4.4.2 Efficiency

The major problems that confront designers and operators of fine screens are clogging (otherwise known as blinding, plugging, felting, matting or hairpinning) and cleaning. As the fine mesh becomes partially clogged it becomes a more efficient straining medium and some screens are designed with this in mind. Baines and Paterson[64] carried out experiments on flow through screens to aid in their design. They studied the pressure drop as a function of screen form and solidity ratio, the capacity of screens to modify the velocity distribution and the turbulence produced by screens. Downes[65] however, considered that a clean fine screen which affords little loss of head gives better removal than a partly clogged screen. He presented data from ten years of operation showing that after cleaning of a fine screen the volume of screenings increased by almost 10% for the following two days.

Perforated plates both punched and drilled are generally used for the screen. Muldoon[5] reported that wire cloth and mesh screens were used but difficulties were experienced in keeping the screens free from clogging. A report commissioned by CIRIA[66] stated that the following factors affected the design of rotating cup screens:-

(i) rate of flow of sewage;
(ii) head loss across screening medium;
(iii) aperature size and plate thickness
(iv) percentage free area of screening medium;
(v) effective submerged area;
(vi) speed of rotation
(vii) nature of raw sewage with regard to suspended solids;
(viii) effectiveness of cleaning mechanism.

McVie[44] from some studies on cup screens found that clogging was frequently unpredictable and outlined certain important parameters affecting the degree of clogging; these included the screen fabric geometry, the thickness of the plate strainer, and the existance of a limiting head for any given opening size beyond which clogging occurs. Both McVie and Mixon[67] discussed Boucher's filtrability index and Mixon developed the relationship between this and the design of rotary drum screens. Osorio[68] cited the use of cup screens at Brighton where the plant handled 2 500 kg dry solids/day. The screen openings were 5mm and the total area of opening of each screen below the water level was $12m^2$. Nominal maximum velocity through the screens was 0.15 m/s. It was believed that the manufacturer's specified maximum peripheral speed of 7.2 m/min would limit clogging to 50% (presumably in terms of openings area), and thus produce a nominal velocity of 0.30 m/s with a head loss of approximately 12mm across the screen. Almost complete clogging did, however, occur in practice and it was considered that this may have been aggravated by the fact that all the screenable solids arrived at the plant between noon and 3pm. Osorio considered that under these circumstances the effective flow capacity of the screen was equal to the width of the screen multiplied by the peripheral speed. A peripheral speed of 25 m/min was subsequently found to eliminate the clogging. More recently research has been carried out by Roebuck[21] to ascertain the relationship between head loss across the screen, speed of rotation and washwater pressure. Tests showed that the important factors governing head loss are the speed of rotation and the concentration of screenable solids (mg/litre) and a theoretical relationship was produced as a basis for design of rotating cup screens.

The self cleaning action of the drum screen was favoured by Besselievre[69]. In this type the drum revolved against the direction of the sewage flow, the solids in the sewage passing underneath and up the other side of the drum; the high speed of rotation causes an artificial head of sewage on the inside, part of which flows out of the drum openings and washes the solids into a screening pit. The mode of action of automatic cleaning brushes for rotary drum screens was discussed by Vosbury[70]. He considered that long slots, formed by close parallel wires, with brushes moving along the slots, to be a good means of avoiding the brush bristles pushing the solids into the drum. Gardner[71] disagreed with this and considered that the path of cleaning brushes should be at right angles to the line of the slots. Greasy effluents further complicate the operation of fine screenings. Benkovitch[72] reported that rotary screens gave better performance than stationary screens for treating grease-laden waste flows. Allen[63] reported that water, steam, compressed air jets or sodium hydroxide have usually been found to be effective for screen cleaning. Roebuck[21] showed in his tests that the optimum washwater pressure for cup screens was 2 bar.

2.4.4.3 Performance

The fracturing of large solids can occur on the screen medium such that they eventually pass through the openings. Allen[63] pointed out that in order to prevent this happening screen designs such as the shovel vane, which provides a gentle uplifting of solids, were developed. He concluded that with openings of 2.5mm, removals of at least 30% suspended solids and 20% suspended organic matter should be achieved from domestic sewage and held that the best fine screening could give removals of 30 to 50% as compared with 50 to 65% for sedimentation. Metcalf and Eddy[23] gave efficiencies for a number of different types of fine screen quoting figures of around 20% for removal of suspended solids from screens with opening sizes of around 1mm. Whereas experiments on fine screens quoted by Keefer[14] gave efficiencies for removal of suspended solids of between 2.7 and 7.5%.

2.4.5 Special Screens

The Hydrasieve is a development of the sidehill screen in which sewage is delivered to a headbox above the screen from where it flows over a weir and cascades down the face of the screen. It is intended to replace bar screens, primary sedimentation tanks and grit removal devices. Whittenmyer[73] reported BOD and suspended solids removal of 20 to 35% at Dayton, Ohio, USA. In the Hydrasieve the screen plate is made up from horizontal wedge shaped stainless steel bars, and is set at three distinct angles of 25^{o}, 35^{o} and 45^{o} to the vertical. Screened sewage flows through the screen whilst the solids travel down the face of the screen and are discharged at the bottom. A 1.5mm bar opening is common for sewage applications. The Hydrasieve has no moving parts and is therefore relatively maintenance free apart from occasional washing down with a stream jet or high pressure hose to remove fat and grease. The frequency of this cleaning depends on the nature of the sewage but an average figure of once every 48 hours has been reported[74] although Benkovitch[72] considered that cleaning might be necessary every few hours for some sewages.

The Rotostrainer, consists of a fine stainless steel cylindrical screen and headbox; sewage enters the headbox and passes through the slowly rotating cylindrical screen. Solids are retained on the surface of the screen and are removed by a wiper mechanism as the screen rotates. The continuous washing action of the falling water prevents grease and fibrous material blinding and clogging the screen surface. Benkovitch[72] reported that this self cleaning action proved to be so effective that manual cleaning of the screen was only necessary every six to eight weeks.

Tests were carried out in 1975 on a raw sewage sea outfall to the Mediterranean[75]. The screen used had a 0.75mm opening, and it was found that during the six week test period no manual cleaning of the screen surface was necessary. The reductions achieved were: suspended solids 40%; BOD 35%; COD 65%.

Sweco Europe and Sweco USA manufacture two types of fine screen suitable for dealing with sewage flows and storm flows: a separator which is a form of vibrating sieve; and a concentrator which is a form of centrifuge with backwashing facility. Sauer[76] described tests carried out in California using a 1.52m diameter concentrator which was found to effect reductions in suspended matter by 80% and settleable solids by 98%. From tests carried out at Portland, USA, Marske[77] concluded that high rate fine screening with the concentrator is an economical method of treating combined storm overflows. The effectiveness of this screen is significantly reduced by the build-up of oil and grease on the surface of the screen and frequent backwashing is necessary when this occurs. Marske[77] did not recommend the use of the Separator at sewage works because of its lower hydraulic capacity and the low levels of removal achieved.

2.5 TREATMENT OF SCREENINGS

2.5.1 Maceration

Maceration is the combined action of pumping and disintegrating sewage screenings. The disintegration is by shearing and cutting actions in the pump. The screenings are then usually returned to the sewage flow. This method of screenings disposal dates back to the beginning of the twentieth century and is considered by some to be the most hygenic and, usually the simplest means of disposal(78). One of the first known installations was at a Moscow Pumping Station(40).

In the UK, macerators have been developed from the 'Stereophagus' type of pump which was used to disintegrate gross solids by a cutting action before discharge to sea. The original patent for this type of pump was granted in 1910 but the first recorded use was at Bournemouth where a 'Gargantua' disintegrator was installed at the sea outfall in 1920(79). Townend(55) recorded that a 'Stereophagus' pump was installed at Broadstairs in 1928. These early macerators were for the whole sewage flow rather than just the screenings. In fact Homewood(79) considered that liquid/solids separation defeated one of the principal objects of maceration i.e. the disintegration of screenings and ultimate dispersal and degradation; whereas, Lupton(80) considered that the maceration of separated screenings and return to flow would supercede the practice of putting the whole flow through a macerator.

In the USA in 1926 a hammer mill type of macerator was tested(7). Most screenings were ground to a fine pulp but some stringy material varying from 125 to 300mm in length remained. The power requirements for this machine was 8.8 kWh/m^3 of screenings at a throughput of 1.5 to 2 tonnes/h. A screenings macerator with cutting teeth was tested in 1936(81); the macerated screenings from a 25mm screen had the appearance of primary sludge, with only a few short fibres, and would readily pass through a 1.2mm screen. The throughput of the macerator was 0.7m^3/h and a power consumption of about 5 kWh/m^3.

The maceration of screenings became popular during the period 1928 - 1935 when sludge digestion(82) became established as a producer of power. In 1930 a 'Stereophagus' pump was installed at Ipswich to macerate screenings, in this case the screenings being flushed into the pump by sludge[83]. In 1934 Lundie[84] reported on trials at Pretoria which had shown that it was possible to digest screenings with sewage sludge in a digester provided that the screenings were sufficiently fine. It was decided to macerate screenings and a 'Stereophagus' type of pump was installed which discharged macerated screenings to the sewage flow ahead of the screens. No difficulties with sludge digestion were subsequently reported. The direct pumping of macerated screenings to a digester has been reported[39,55] but this does not appear to have been common practice.

Several authors[85,86,87,88,89] noted increases in digestor gas production following the introduction of macerated screenings into digesters. Watkins[85] claimed a surprising 50% increase with greater uniformity of production whereas Sulzer Bros., Limited[88] claimed only a 5% increase. The use of comminutors for the disintegration of screenings has also been reportable[90]. Fears of detrimental effects on primary sedimentation were proved to be unfounded[89]. Though this is not an opinion shared by all authors, Metcalf and Eddy[47] reported that some engineers are of the opinion that it is undesirable to grind up the screenings and return them to the flow, because the shredded rags frequently collect in clumps or balls to cause operating difficulties in the units that follow; whilst other engineers are of the opinion that this method of disposal is the simplest and cleanest solution of a disagreeable problem. The problem of 'cores' forming in sludge filter presses following return of macerated screenings to the flow is mentioned by the YWA[91]. In a recent paper Tricker and Thorpe[92] described the operation of a new works stating that the macerators never worked successfully for long periods and, after problems with maintenance and shredded rags in downstream treatment units, were removed and the screenings buried. Problems have generally been with the macerator itself, Schatzle[93] mentioned that maceration had to be abandoned due to excessive blade wear resulting from grit in the screenings, whilst Keefer[14] merely noted the need for proper maintenance. Some authors[94,87] have stated that the process of maceration and return to flow does not increase the amount of scum in digesters but the Water Pollution Control

Federation[38] considered that scum control is needed if this method of screening disposal is used and Fischer[95] reported difficulties of scum formation in sludge digesters with maceration. Wyman[96] found that at a plant with two 36" comminutors, comminuted solids increased the sludge output by about 2%.

Other grinding devices have been devised, e.g. the 'Jeffrey' grinder[60]. This machine was considered to have a long life but a disadvantage was the need for uniform feed of screenings.

The importance of the macerator discharge point is mentioned by several authors. IWPC[13] consider that it should preferably be upstream of the screen, a view shared by Escritt and Rich[19] though they consider that if the discharge is not upstream then it must be into rapid flowing water otherwise the hair content causes the shredded screenings to felt into mats. The YWA[91] found that moving the discharge point from downstream to upstream of the screen did not cure problems in the rest of the works.

Increasing use of disposal items has resulted in blockages after the screens at Basingstoke sewage works. Screenings treatment was by maceration and return to flow but pressing and subsequent incineration of screenings were being considered due to frequent blockages[97].

2.5.2 Comminution

Comminution is the shredding of the coarse solids in sewage without the solids being removed from the sewage. A comminutor consists of a large hollow drum with horizontal slots, rotating continuously on a vertical axis. Coarse solids retained by the screen are shredded by the action of teeth on the outside of the drum engaging fixed steel combs and the solids are shredded until fine enough to pass through the slots with the sewage. Comminution therefore retains all the solids in the sewage flow and can be considered as having the effect of screening, maceration of screenings and return to sewage flow. A problem with the operation of comminutors, reported by several authors[96,98] is that when rags pass through the machine they tend to be cut up into long strips which become tangled in pumps and elsewhere. The authors suggested that a bar screen placed downstream of the comminutor provided a remedy.

With any cutting device attention has to be paid to the degree of wear of the blades and other moving parts. Earp[99] considered that wear is proportional to the amount of grit in the sewage, and that normal maintenance should usually be confined to ten minutes spent everyday on greasing. Clearly the required maintenance varies with the nature of the waste; Morgan[100] considered the time required for routine maintenance to be a negligable quantity with lower teeth needing re-sharpening or replacing anywhere from every few eeeks to once every year or two depending on the amount of grit. Heynike[98] mentioned that, at Pretoria, accumulated waste in front of comminutors had to be removed every two hours despite the provision of a baffle in front of the machine. In addition, a mass of stringy material (28 l/d) was found in the comminutor drum on daily cleaning. At Marion in Indianna, Backmeyer and Ross[101] reported that teeth usually need grinding every 90 days and that after seven months operation machines were taken out for a complete overhaul. Replacement of the drum when the ribs of the screen bars in the drum were worn, occurred usually after about 100 months, which may be considered the overall lifetime of the machine from the point of view of the replacement of major parts. Lifetimes of the various wearing parts have been found by Heynike[98] in South Africa to be:

two sets of tungsten carbide teeth	330 days
one set of vertical cutter bars	400 days
bottom comb	380 days
top comb	450 days

Merz[35] has found that it is more economical to have teeth sharpened regularly rather than to use them continuously to the point when they need to be replaced.

Earp[99] mentioned that head loss could be another source of difficulty. He stated that if the head loss through the comminutor is too great, solids would tend to be forced through the slots without being sufficiently ground up.

2.5.3 Pressing

In view of the objectionable nature of screenings and the need to minimise land requirements for disposal, there has been a trend in recent years towards the dewatering and/or incineration of screenings. Screenings cannot be incinerated effectively without some degree of prior dewatering and accordingly mechanical processes have been developed to reduce moisture levels to below about 70%.

For small quantities of screenings simple drainage may suffice and Cameron[102] considered that about 33% water loss could occur in four hours by this means. In the absence of dewatering other than drainage, the capacity of a screenings incinerator would need to be increased by about 50%, although in some cases the cost of a larger incinerator may be balanced by the savings achieved through eliminating a dewatering process. Cameron[102] pointed out that, it might be feasible to use excess digester gas for evaporating the excess water from the screenings rather than resort to mechanical dewatering.

Dewatering of screenings is controlled by three important operational factors, namely:

1. Pressing pressure
2. Pressing time
3. Number of applied press loads

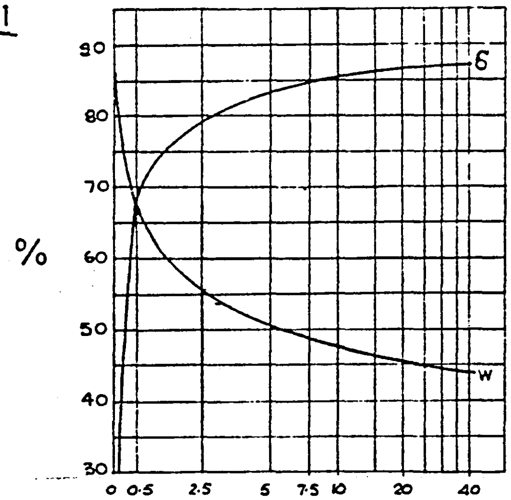
Each factor has a contributing effect on the degree of dewatering, as is shown in the following graphs, Figures 2.4 to 2.6[103].

The first graph shown that up to 0.5 MN/m^2 the dewatering increases steadily but about this figure no appreciable increase is achieved.

The second graph shows the influence of the pressing time on the press operation. The optimum pressing time appears to be about 10 seconds.

The third graph shows the effect of the number of separate pressings at a constant pressure and reveals that there is not a great advantage in performing more than two pressings per screenings charge.

No. 1



Pressing Pressure

in MN/m^2

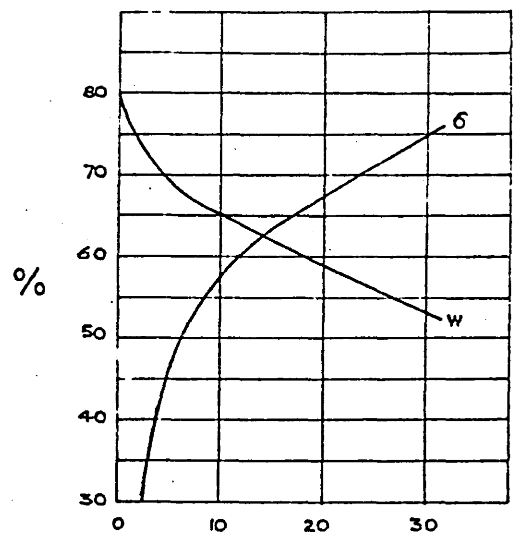
Fig. 2.4 Dewatering efficiency & water content of pressed screenings as a function of Press pressure

NOTE:

W = % water content of screenings

6 = % dewatering of screenings

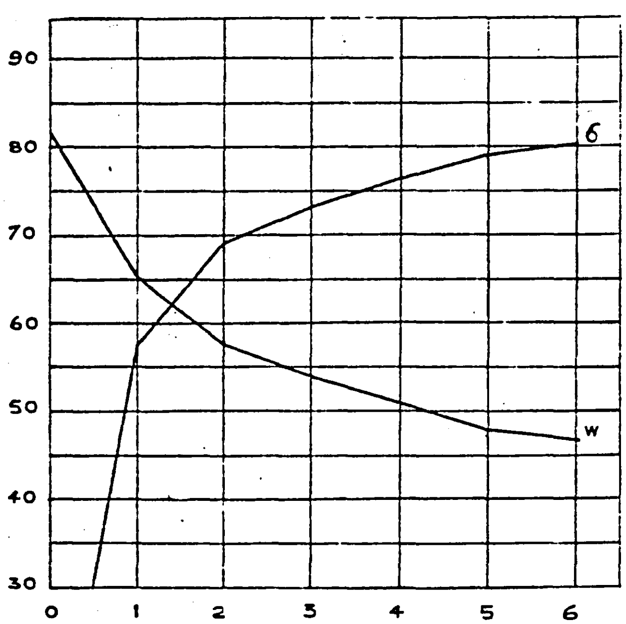
Graph No. 2



Pressing time in sec.

Fig. 2.5 Dewatering efficiency and water content of pressed screenings as a function of pressing time Pressing Pressure = $5.5 MN/m^2$

h No. 3



No. of pressings

Press duration = 10 sec.

Pressing Pressure = $5.5 MN/m^2$

Fig. 2.6 Dewatering efficiency and water content of screenings as a function of number of pressings

It is possible to apply too great a pressure to screenings, which results in plasticisation of the organic matter and its discharge from the unit with the filtrate. Indeed Busse[104] pointed out that at pressures of between 4 MN/m^2 and 5 MN/m^2, apple and lemon peelings could be plasticised.

Details of a Swedish dewatering press have been reported by Dunkers[105]. The pilot press consisted of a long semi-circular pipe with a mobile pressure plate which produced a maximum pressure of 2.5 kg/cm^2. An average weight reduction of 67% was achieved together with an average volume reduction of 80%. A full-scale press has since been constructed to handle the screenings from about 150 000 people and results similar to those from the pilot press have been obtained. Included in the system is a bag filler to provide for the automatic packing of pressed briquettes.

The Northumbrian Water Authority (NWA)[106] has recently investigated six screenings presses. The Harleyford Hydrosand Screenings Press, consists of a horizontal flat conveyor belt supported on a variety of drum centres, above which is another separate driven smooth pressure belt. The pressing action is achieved by forcing the screenings through the constriction formed by the two belts. The press has a capacity of 1 tonne/h and a belt speed of 6 m/min. The weight and volume reductions achieved during the investigation were 50% and 30% respectively. It was considered to be rather messy in operation and possibly to have problems with large solids; however, the manufacturers were said to be rectifying these faults. The NWA also tested a Sludge Dewatering Limited press which was developed from a refuse compactor. In this system a hydraulically operated ram compressed the screenings in a chamber. Its capacity is 2.7 m^3/h and it reduced the moisture content to 45%. A Danish Bias press, also considered, produced bales of screenings on a similar principle. The moisture content was reduced to between 60% and 70%, and the volume reduction was 50%. This press has a smaller capacity of 0.2 - 0.8 m^3/h. The fourth device to be investigated was a German Geiger press. Initial pressing is by a drum at the entry to the press from a feeding chute, and final pressing achieved through a mangle action between two drums. The moisture content of screenings was reduced to 60%; the two standard models can handle 5.0 and 2.5 m^3/h. It was found that this press successfully crushed a brick and passed a four metre length of timber without difficulty. Another German press manufactured by Passavent was also tested. This employed the principle of a low pressure hydraulic chamber followed by a high pressure chamber, after which the screenings were forced into a final dewatering chamber for repeated pressings. The moisture content of the screenings was reduced to between 50 and 60%. Systems with a handling capacity of $0.7m^3/h$ to $6.6m^3/h$ are available. The last press investigated was that of Hawker Siddeley Water Engineering. This consists of a hydraulic ram which pushes screenings into a perforated pressing area. The ram pressure was 105 kg/cm^2 and the weight and volume reductions attained were 40 to 60% and 30 to 40% respectively. The NWA noted its easy maintenance. All the presses surveyed by the NWA may be used with a continuous feed system.

2.5.4 Washing and Centrifuging

Little has been written regarding screenings washers Coggan[107] noted the installation of one at Rodbourne STW in 1953 and in the same year it was reported[108] that one was installed at Budds Farm STW. The washer was described as a machine which macerated organic matter under high pressure water sprays, the organic matter and washwater being returned to the flow and the debric, etc., being discharged from the machine in a clean state.

Centrifuges have been used for the dewatering of screenings. Sutherland[109] discussed the use of centrifuges in sewage treatment and considered that a suitable application would be the dewatering of screenings. Centrifugal screenings dewatering plants have been installed at Jamaica, New York, Minneapolis and Milwaukee[8,110]. Flood[7] also described tests with various types of centrifuge which again gave average reductions in moisture content to about 65%. Allen[6] reported that when 1250 kg of fine screenings which had been allowed to drain briefly and had a moisture content of 85%, were placed in bags and dewatered in a Laundryette centrifuge the moisture content was reduced to 65% and the screenings could be incinerated by the addition of 25% by weight of coal. Keefer[14] reporting on the installation at Milwaukee stated that with a load of about 320 kg it took from 10 - 25 minutes to reduce the moisture content 88 to 61% for coarse screenings and from 92 to 78% for fine screenings.

2.6 LANDFILL

2.6.1 Disposal of Screenings

Since screenings have a high moisture content, Bloodgood[40] considered that they should be drained in perforated cans before burial. Problems with this method of disposal may occur in the handling of screenings due to their objectionable nature, and from birds and rodents being attracted to the disposal area[27]. To prevent the nuisance of flies and rodents before the screenings are coveres, sprinkling with calcium chloride or lime has been suggested[111].

Flood[7] suggests that screenings shall not be buried too deeply, as they will decompose slowly if removed from the upper layers of earth in which bacterial activity is greatest. Instances of very slow decay of the buried screenings have been found and Rawn[112] reported that four years after burial, screenings showed little deterioration. Similarly, Appleton[113] found that in 2.4m deep pits covered with 0.6m of sand, there was little evidence of decay after 27 months.

The IWPC suggest in their recent publication[13] that this method of disposal is often unsatisfactory on larger works, although bagging of the screenings before burial reduces the likelyhood of nuisance. Furthermore, with the bags used being usually synthetic and with the unscreened amounts of plastics and synthetic fibres in screenings, they consider that this method is less desirable than it used to be.

The alternative to burial on site, is burial with refuse on municipal refuse tips, mentioned by various authors[73,111,114].

2.6.2 Composting

Treatment of screenings to produce a compost or similar has been widely attempted with varying results. Fine screenings have been composted at New Jersey, USA, in open cells[115]. These cells were cleaned out annually and were not particulary offensive. Composting at Low Angeles has been carried out in open pits 3.8mm square by 3m deep[112]. Screenings and skimmings were treated at a rate of 0.57 - $0.7m^3$/day - about 1.8 kg dry weight/day/m^3 tank capacity. Provision of capacity for 60 days digestion in the presence of 50% by volume of seeding material (sludge) was advised. Pumps were not suitable for moving the material because of scum troubles.

Some wartime experiments in London have been reported by Vick[116]. He outlined the production of compost from a mixture of domestic refuse and sewage sludge screenings, the latter derived from screening sludge from sedimentation tanks. This compost was found to be as effective as farmyard manure when applied to land growing cabbages and other root crops. The compost was produced by tipping refuse and screenings (1:1 by volume) into pits in alternative layers, 0.3m thick, and leaving for a week before removing to a concrete slab where the compost matured for a total period of about 3 months before use.

In the discussion on Vick's paper, Stanbridge quoted results from New York for compositing disintegrated centrifuged screenings with 2% gypsum by weight and 2% cut straw by volume and compared these with results from London.

	New York	London
Moisture %	35.2	15.2
On dry basis		
Nitrogen	2.60	1.15
Phosphoric Acid	1.21	1.08
Ash	14.80	68.44

The New York compost had a high manurial value and did not contain pieces of broken glass and crock which always spoilt compost made from household refuse.

There were various other attempts in the 1920's and 1930's to produce fertiliser bases, composts or materials which act as humus, Methods found to be successful were heating under pressure[117], digestion with steam for 6 to 8 hours[118,119], drying followed by spreading on land[120], and burial with lime[121].

2.6.3 Digestion

This section deals specifically with the anaerobic digestion of screenings. The effects on the digestion of sewage sludge containing screenings arising from comminution or the return of macerated screenings are considered separately in Section 2.5.1.

Detailed results of digestion experiments using fine screenings were reported by Rudolfs and Heisig[4] who showed that, with a detention time of 40 days at a digester temperature of 27°C, it was possible to achieve solids and volatile matter reductions of 61% and 67% respectively, with a gas production of 0.33 m^3/kg dry solids added. The sludge produced from the digester was odourless and exhibited good drying characteristics. An optimum digester capacity of 2.4 litre/hd was proposed.

The formation of scum during screenings digestion can be a serious problem because of the tendency for the fibrous material present in the screenings to rise to the surface, thereby trapping the gas in the digester. A method of overcoming this problem by mixing the screenings with digested sludge before being fed to the digester has been patented by Imhoff[122]. Another method of preventing scum formation has been developed by Boruff and Buswell[123], who designed a digester containing a rotating wire-covered drum. The rotation of the drum ensured adequate mixing and prevented scum formation. The system was claimed to produce about 0.34m^3gas/kg dry screenings when operated within the range 24 to 34 kg wet screenings/d/m^3 digester capacity.

A number of experiments have been carried out with the addition of enzymes to digesters but no noticeable effects on digestion efficiency were observed and low gas yields at normal digestion temperatures[124,125] were recorded.

The digestion of coarse screenings with a high proportion of non-organic matter was carried out in open pits at Los Angeles by Rawn[112].

2.6.4 Incineration

The original method of screenings incineration was as a fuel in boilers. Kinnicutt, Winslow and Pratt[127] reported the incineration of dried screenings mixed with coal for this purpose.

The first screenings incinerators were of the box type, fed either from the top or side, generally by hand, the screenings being hand raked on the grate to ensure effective incineration. The Dutch oven incinerator at Long Beach, USA, described by Appleton[113] had a grate area of $5.7 m^2$ and could accept a charge up to 1880 kg. In a later paper describing the same installation, Paterson[128] quoted a throughput of about 8 tonnes/24 hours and, although originally fed manually, it had been converted so that the screenings were blown into the incinerator by compressed air.

Problems have been encountered with the feeding of screenings incinerators, and charging hoppers should be designed to allow for manual stoking, e.g. Stilson[129] reported that with gravity feeding, screenings tend to bridge across the charging gates due to expansion resulting from the heat radiated from the incinerator.

The Aurora incinerator[130] had a storage bin at the rear of the incinerator with a perforated false bottom to allow drainage of of screenings. Cameron[102] considered that experiences have demonstrated that it is necessary to dewater screenings adequately prior to incineration, and in one instance drainage for four hours in perforated bins had proved satisfactory. Several authors noted that at the majority of works screenings were usually dewatered by pressing prior to incineration. Odour problems from screenings storage hoppers may be eliminated[130] by taking air for the incinerator draught fans from the hopper.

For the box type of incinerator Stilson[129] considered that the loading on the grate should be within the range 122 to 136 kg of wet screenings/m^2.

Both Flood[7] and Stilson[129] recommended a minimum operating temperature of $676^{\circ}C$ in order to ensure complete combustion of all noxious gases and a maximum operating temperature of $871^{\circ}C$, above which ashes tend to slag is given by Stilson[129]. This is borne out by Appleton[113] who reported that the clinkering point of screenings was about 1065°C.

Lewers[131] reported that a multi-hearth furnace had been used in incinerate screenings, the gases from the upper hearths being fed into the burning zone to destroy odours. The calorific values of the screenings varied between 16280 and 20930 kJ/kg at 70% moisture content; no additional fuel was required for incineration other than for start-up. Keefer[14] quoted calorific values for dry screenings within the range 13960 and 23260 kJ/kg which compared with values of 19770 to 24420 kJ/kg quoted by Stilson[129].

The amount of fuel required to incinerate crude non-dewatered screenings has been reported by various authors and both Flood[7] and Keefer[14] stated that the fuel requirement varies from 3230 to 8140 kJ/kg of screenings and is dependent upon the moisture content, type and condition of the incinerator and the method of operation.

In the case of the rotary drum type installation at Pretoria Nicolle[94] reported that approximately 57m^3 of digester gas are needed to burn 160kg of screenings at 75% moisture content in one hour. Metal hooks were set in the side of the drum to pick up the screenings and assist incineration.

The amount and composition of the ash removed from screenings incinerators are given by both Appleton[113] and Paterson[128] for the same installation. Comparison of results is impossible but the following ranges were reported: a residue of 1 to 2.5% by weight of screenings burnt (as received), the ash containing 4 to 11% phosphoric acid, 0.4 to 2.9% potassium oxide, 1.8% sodium oxide, 46% silica and 0.45% ammonia. It was also noted by Paterson that the ash was used in local gardens as a fertiliser.

Stilson[129] further recommended that no cast iron parts be used in areas that can be reached by ash as the cast iron is badly slagged by the ash from screenings. In a subsequent paper[22] the same author noted that for optimum efficiency incinerators should be operated within 75 to 150% of their rated capacity and that, in determining the heat balance, the amounts of fixed and volatile carbon in the screenings should be ascertained by accurate analysis.

In the UK, according to Stanbridge[45] attempts to incinerate screenings have usually been abandoned because of the cost and odour nuisance. A destructor was installed at Beckton in 1891, and incinerators using sludge gas at Falkirk in 1924 and at Bothwellbank in 1938. The latter incinerator was only used for burning large rags which could not be macerated[17].

The first mention of the incineration of screenings with sludge is made by Stilson[22] who suggested that it is practicable providing that screenings are fed into the incinerator slowly. The incineration of screenings together with municipal refuse was first considered by Flood[7] who considered that the screenings should first be dewatered. This is borne out by Keefer[14] who, whilst concurring that the incineration of screenings along with municipal refuse is a practical method of disposal, found that attempts to burn wet screenings at 85% moisture content in a refuse incinerator proved unsuccessful.

Karnovsky[132] stated that incineration of screenings alone at sewage treatment works had been found to be more expensive than at a municipal refuse incinerator. However, trials had shown that there is a need to dewater the screenings before burning with refuse and that screenings can be burnt after pressing at a municipal refuse incineration plant without loss of combustion efficiency.

2.6.5 Transportation and Handling

Due to the offensive nature of screenings, screening installations require designing to minimise the handling of screenings, but as recently at 1977 it was still being said[133] that the problems of handling and transporting have not been satisfactorily resolved. Whilst many authors emphasize the need for prompt and effective disposal of screenings due to their offensive nature little has been written on the methods of achieving this aim. Methods of transportation mentioned have included wheelbarrows, wagons, covered refuse cans, belt and screw conveyors, sparge channels and pneumatic ejectors. Open storage cans or uncovered conveyors are not recommended[38] as they can become fly or insect breeding places and in the case of cans handling hand-raked screens perforated cans with removable covers are suggested[14].

The WPCF[38] also recommends that conveyors are kept as short as possible for sanitary and economic reasons. The problems of dry handling of screenings on belt conveyors are dealt with by Calvert and Haseldine[134] who mention the difficulties due to the sticky nature of screenings.

There is a tendancy for the screenings as they drop onto the belt to splash and deposit grease on the inside of the belt. This is transfered to the rollers and causes the belt to run out of line and jamb. It is also difficult to make adequate provision for scraping the screenings off the belt.

The same authors[134] state that handling screenings wet in troughs with sparge water is generally a more effective way but only if the ultimate disposal is through a macerator feeding back into the sewage flow. Whilst this is generally the system used with sparge channels, the YWA[91] describe a system where the sparge water after maceration discharges onto a fine screen the water being returned to the sewage flow and the screenings removed to tip. Pneumatic ejectors are used principally in the USA and there use is described by a number of authors[38,128] though they are considered not to be satisfactory when screenings contain excessive amounts of rags or sticks[38].

In the design of sparge channels and conveyors the following design criteria have been proposed[135]; sparge water, minimum velocity 1m/sec, conveyor belt minimum speed 7.6 m/min.

2.7 COSTS

Very little useful long-term information has been published regarding the actual costs of screening or screenings disposal, however, two recent reports do give this type of information. In the first, a Construction Industry Research and Information Association report[136] published in 1977 comparative costs of various items of screenings equipment and combinations of items are given in the form of a graph (Fig. 2.7) and from the graph the following observations were made.

1. Comminutors appear to be competitive with curved bar screens for populations up to about 40 000 and with grab screens for populations up to about 70 000.

2. A curved bar screen, macerator and return to flow appears to be very economic for all populations above about 50 000.

3. As expected due to its more complex design a cup screen has a much higher capital cost than coarse screens particularly for large populations.

4. A drum screen, macerator and Hydrasieve have a lower capital cost than a cup screen, Rotostrainer and a press.

5. As the population increased, the provision of a screenings press, bagging unit or incinerator becomes more economical.

The second report[137] also published in 1977 set out to produce costs functions suitable for preparing reliable estimates for planning purposes, Referring to a base date the report contains a mechanism to allow for up-dating costs. This report gives the following formula for estimating costs: (base date 1976; third quarter)

(a) Mechanically Raked Screens

$$\text{Cost/screen} = 9.87 \times (\text{submerged area})^{0.39}$$

(b) Comminutors

$$\text{Cost/machine} = 2.22 \times (\text{max. design flow})^{0.27}$$

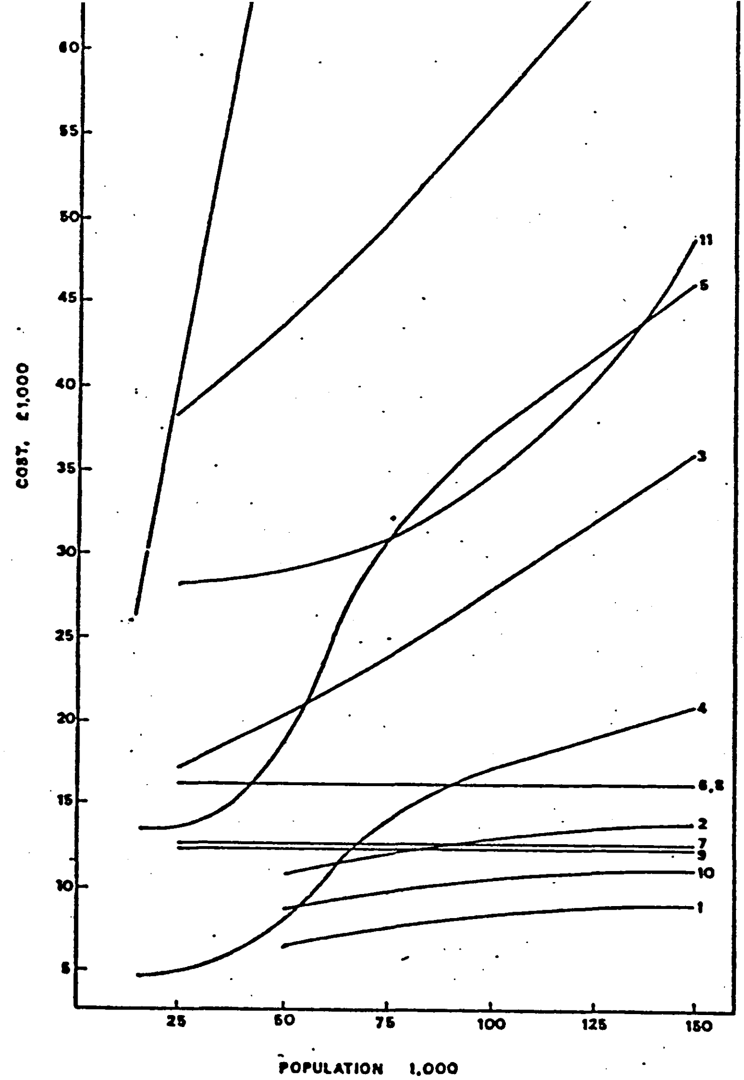


Fig. 2.7 Capital Costs of Screening Equipment (Base date: January, 1977)

Legend

1. Curved Bar Screen
2. Grab Screen
3. Cup Screen
4. Comminutor
5. Screezer
6. Incinerator
7. Press (coarse screenings)
8. Press + Bagging Unit (coarse screenings)
9. Roto Disintegrator
10. Curved Bar Screen + Macerator
11. Drum Screen + Macerator + Hydrasieve
12. Cup Screen + Rotostrainer + Press
13. Hydrasieve

NOTE

(i) The details given in Fig. 2.7 are not for comparison purposes as the various items of equipment do not have comparable efficiencies.

3. QUESTIONNAIRE SURVEY AND VISITS

3.1 QUESTIONNAIRE SURVEY

At the beginning of this project questionnaires covering 116 sewage treatment works were sent out to the Regional Water Authorities in England and Wales and to the Regional Councils in Scotland. The questionnaires were designed to obtain information on current screenings practice and to ascertain the nature and extent of problems associated with screens and screenings. Of these questionnaires 95 were completed and returned. In addition, 11 communications were also received from sewage works which had not been forwarded a copy of the questionnaire.

For the purposes of the survey, sewage works were divided into four classes, based on population served and not on dry weather flow. Sewage works serving populations in excess of 200 000, 75 000 and 20 000 are referred to as large, medium and small respectively. Those works serving populations of less than 20 000 are referred to as very small.

It was decided as a general rule not to survey works containing a high proportion of trade waste in the sewage, especially those serving industries which could effect the nature and quantity of screenings, and those with an even distribution of pumped and gravity flow.

The information abstracted from the returned questionnaires is summarised in Table 3.1.

3.1.1 Screenings' Volumes

Screenings' volumes data were obtained for some 27 sewage treatment works and are summarised in Table 3.2. Examination of the data indicated no apparent correlation between screenings' volumes and sewage flow treated, but some correlation with population served. This would appear to imply that population and flow are not related, which is clearly untenable and the anomaly may be accounted for by variations in the contribution from trade effluents and infiltration, and in the moisture content of the screenings.

Moreover a wide variation in the quantity of screenings is revealed, even for sewage works with similar screen sizes; further examination shows most screenings' volumes to be within the range 0.01 - 0.03 m^3/day per 1000 population. These figures are applicable for normal flows only; in times of storm the amount of screenings arriving at a sewage works on a given period has been found to be up to seven times the amount in dry periods. Sufficient data are not available to enable predictions of the volume of screenings from fine screens, it is considered that volumes may be up to four times that expected for a typical coarse screen (20mm opening). The survey showed that one of the commonest problems encountered at inlet works was the overloading of the screening plant at times of storm; of the 106 works surveyed 14 reported this problem.

3.1.2 Separation Practice

The results of the questionnaire survey reveal that about 70% of the works surveyed screen their sewage and remove the screenings from the flow either for disposal or for return following treatment, and of these 17% report problems solely associated with the screens. The problems reported were chiefly mechanical, though at five works it was noted that the screening plant is considered to to absolute.

The questionnaire requested that screens should be classified, depending upon opening size, into one of three groups. These groups were (a) openings larger than 35mm, (b) openings between 35mm and 20mm, and (c) openings less than 20mm. The returns indicate that there is some confusion over the metric equivalent of the imperial $\frac{3}{4}$" opening size; this size being variously noted as 19mm or 20mm, and thereby affecting the screen classification. Many returns did, however, indicate the actual screen opening size at a particular works and therefore whilst it is possible to make certain observations, listed below, regarding preferred screen sizes, these are limited by the choice of classification.

(a) less than 10% of the works surveyed have primary screens with openings greater than 35mm

(b) for the two largest classes of works the most common screen opening size is 19mm.

(c) in the smallest class the most common screen opening size is 25mm

Table 3.1 Summary of Results from Questionnaire on Screening Practice

Population served - greater than 200,000

Sewage works name	Population served	D.W.F. (m^3/d)	Percentage trade waste in raw sewage (% of D.W.F.)	Percentage pumped flow	Screening practice: Screens (screen openings in mm) or comminutors	Screening practice: Screenings treatment	Screening practice: Screenings disposal	Volume of screenings (m^3/ 1000 head.d)	Problems encountered or comments
Coleshill	203,000	77,000	15	0	Screens (40)	Maceration	Return to Flow	-	-
Minworth	988,000	438,000	30	0.01	Screens (40)	Maceration	Return to Flow	-	Inefficient maceration of storm screenings
Bolton	248,000	82,300	26	5	Screens (25)	-	Burial	0.013	Storm screenings
Bradford	330,000	94,500	33	15	Screens(> 35)	-	Tipped	-	-
Bristol	300,000	140,000	9	100	Screens (20)	Comminutors	Return to Flow & Incineration	0.007	Inefficient maceration by comminutors
Coventry	320,000	96,000	23	0	Screens (25)	Maceration	Return to Flow	-	Access to macerator storm screenings
Dartford	756,000	186,360	13	0	Comminutors		-	-	'Balling up' of rags
Harlow	300,000	72,000	25	0	Screens (19)	Maceration	Return to Flow	-	Freezing of sparge pipes. Damage to macerators by steel objects.
Hertford	516,845	110,000	30	100	Comminutor Screens (20)	-	Burial	-	Screens (12) downstream of comminutors
Knostrop High Level	313,000	70,000	12.2	0	Screens (19)	-	Burial	-	-
Beckton	3,000,000	818,200	12.5	0	Screens (19)	Maceration	Return to Flow	-	'Balling up' after maceration
Beddington	350,000	86,150	6	45	Screens (19)	Maceration	Return to Flow	-	'Balling up' after maceration. High cost of maintenance of macerators
Crossness	1,600,000	500,000	8	97.3	Screens (25)	-	Burial	0.005	-
Deephams	640,000	178,600	12	100	Screens (65) Comminutors	-	Tipped	0.001	'Balling' up of rags
Hogsmill	208,000	48,540	1		Comminutors	-	-	-	'Balling up', now changed to 6mm slot.
Mogden	1,430,000	446,260	17	33	East : Screens (19) West : Comminutors	Maceration	Return to Flow	-	'Balling up' of rags with comminutors.
Riverside	350,000	86,800	25	0	Screens (75) Comminutors	-	-	0.007	Screenings collect under rake at base of screen
Manchester	800,000	310,000	34	0	Screens (12)	-	Burial	0.008	Storm screenings
Nottingham	456,386	146,000	27.6	40	Screens (22)	-	Burial	0.007	-
Sheffield	510,000	145,500	25	7	Screens (19)	Maceration	Burial	-	Maintenance of macerators

Sewage works name	Population served	D.W.F. (m³/d)	Percentage trade waste in raw sewage (% of D.W.F.)	Percentage pumped flow	Screening practice: Screens (screen openings in mm) or comminutors	Screening practice: Screenings treatment	Screening practice: Screenings disposal	Volume of screenings (m³/ 1000 head.d)	Problems encountered or comments
Bath	92,000	22,260	2	100	Screens (19)	Maceration	Return to Flow	-	-
Bedford	90,000	29,000	12	100	Screens (35)	-	Burial	-	Storm screenings
Blackburn	120,000	65,000	45	0	Screens (6)	-	Burial	-	Storm screenings
Brockhurst	83,300	28,000	33	0	Screens (65)	-	Tipped	0.01	Mechanical equipment
Cardiff East	85,000	45,000	12	0	Comminutors	-	-	-	Comminutors expensive to maintain
Cardiff West	100,000	35,000	5	0	Comminutors	-	-	-	Comminutors expensive to maintain
Chelmsford	92,500	27,200	7	5	Screens (< 20)		Burial	-	Finer screen required
Cheltenham	95,000	36,300	21	10	Screens (19)	Maceration	Return to Flow & Burial	0.011	'Balling up'
Chertsey	80,000	18,200	5	100	Screens (19)	-	Burial	0.009	-
Chesterfield	81,000	16,200	23	0.05	Screens (19)	-	Burial	0.02	-
Darlington	86,000	27,820	25	0	Screens (25)	Maceration	Return to Flow	-	Mechanical equipment
Derby	192,500	99,968	60	7	Comminutors	Pressing [a]	Burial		'Balling up'
Dewsbury	115,000	42,500	14	97	Screens (5)	-	Burial	0.02	Fibrous materials
Doncaster	85,000	24,300	16	100	Comminutors	-	-	-	'Balling up'
Halifax	85,500	37,000	18	1	Screens (19)	Maceration	Return to Flow	-	Maceration - excessive wear due to stones
Knostrop Low Level	170,700	80,000	23	100	Screens (16)	-	Burial	-	Obsolete plant
Liverpool	189,000	39,000	28	100	Screens (25)	Maceration	Return to Flow	-	-
Kew	90,000	34,400	5	3	Screens (19)	-	Burial	0.008	-
Luton	117,000	37,300	27	0	Screens (38)	-	Burial	0.017	Obsolete plant
Monmouth	102,000	22,000	25	0.7	Screens (< 20)	Maceration	Return to Flow	-	Damage to macerators by steel objects
Northampton	130,000	51,000	15	0	Screens (19)	-	Burial and Incineration	0.023	Bearing and gate faults with incinerator
Norwich	170,000	39,300	21.8	100	Screens (6) (Rotary Cup)	Maceration	Return to Flow	-	Transportation of screenings. Macerator blockages.
Penybont	85,000	23,000	6	0	Comminutors	-	-	-	-
Reading	145,000	49,000	12	100	Comminutors	-	-	-	'Balling up'
Rochdale	85,250	37,300	25	0.1	Screens (20)	Press	Incineration		
Slough	121,200	36,900	20	100	Comminutors Pre-screened (20 - 35)	-	-	-	
Millbrook	79,000	36,800	21	100	Comminutors	-	-	-	Storm screenings
Swansea	128,300	36,360	4	0	Screens (19)	Maceration	Burial	-	-
Swindon	125,000	26,000	15	100	Screens (19)	Press	Burial	0.018	-
York	110,000	36,000	21	100	Screens(20-35)	-	Burial	-	Maintenance

(a) Press for screenings on sludge pipeline.

Sewage works name	Population served	D.W.F. (m^3/d)	Percentage trade waste in raw sewage (% of D.W.F.)	Percentage pumped flow	Screening practice: Screens (screen openings in mm) or comminutors	Screening practice: Screenings treatment	Screening practice: Screenings disposal	Volume of screenings (m^3/1000 head.d)	Problems encountered or comments
Altrincham	38,000	10,590	3	0	Screens (22)	-	Burial	0.008	-
Ashton	44,280	10,000	10	0	Comminutors	-	-	-	-
Billingham	21,600	11,300	31	0	Screens (19)	Maceration	Return to Flow	-	Storm screenings
Bournemouth	45,000	25,000	4	10	Comminutors	-	-	-	Storm screenings
Bradford	32,000	11,200	41	0	Comminutors	-	-	-	-
Brighouse	46,000	16,900	9	0	Screens (25)	Maceration	Return to Flow	0.02	Storm screenings
Burnley	63,500	19,000	30	0	Screens (22)	-	Burial	-	Rodents
Buxton	20,000	6,500	Trace	10	Comminutors	-	-	-	-
Carlisle	75,000	33,000	28	5	Screens (25)	-	Burial	-	Rake cleaning mechanism inefficient
Chester	75,000	18,000	8	2	Screens (25)	Maceration	Return to Flow	-	-
Christchurch	35,400	12,200	1.8	100	Screens (<20)	Maceration	Return to Flow	-	Maceration
Crewe	52,500	18,200	18	0	Screens (19)	Maceration	Return to Flow	0.006	'Balling up'
Darwen	29,000	11,400	50	10	Screens (20-35)	Maceration	Return to Flow	-	-
Doncaster	20,000	6,808	47	85	Comminutors	-	-	-	-
Dunfermline	55,000	18,200	0	-	Screens (<20)	Maceration	Return to Flow	-	-
Durham	25,000	4,000	0	0	Comminutors	-	-	-	'Balling up'
Grantham	26,650	8,000	12	0	Screens (25)	-	Burial	-	Storm Screenings
Harrogate North	30,000	7,000	0	0	Screens (20-35)	-	Burial	-	-
Harrogate South	31,000	10,000	15	4	Screens (20-35)	Maceration	Return to Flow	-	Storm screenings
Hereford	47,200	42,800	60	0	Screens (10) (Drum)	Maceration	Return to Flow	-	-
High Wycombe	65,000	29,000	9	0	Screens (20-35)	Maceration	Return to Flow	-	-
Hyde	40,000	18,900	50	5	Screens (20-35)	-	Burial	-	-
Kendall	20,000	7,450	15	0	Screens (<20)	-	Burial	-	Obsolete plant
Kettering	47,000	15,900	3	0	Screens (38)		Burial	0.028	Storm screenings transportation
Radley	45,500	10,000	6	0	-	-	-	-	-
Lincoln	78,200	17,500	13	100	Screens (12)	-	Burial	-	Obsolete plant. Moving parts in flow
Redbridge South	30,000	5,600	0	0	Screens (25)	-	Burial	0.007	-
Worcester Park	72,000	16,360	3	55	Comminutors	-	-	-	Balling
Newbridge	20,000	10,700	51	10	Screens (>35)	-	Burial	-	Rake mechanism
Perth	40,000	21,600	23	0	Screens (19)	Maceration	Return to Flow	-	Macerator
Camels Head	63,600	10,300	2	7	Screens (19)	Maceration	Return to Flow	-	-
Plympton	34,300	10,800	10	7	Comminutors Screens (20)	- Maceration	- Return to Flow	-	Screened after comminution
Pontypridd	70,000	25,000	8	-	Comminutors	-	-	-	Balling
Coisley Hill	42,000	4,400	0	0	Screens (16)	Maceration	Return to Flow	-	-
Portswood	75,000	11,300	18	75	Screens (18)	Press	Tipped	-	Storm screenings
Woolston	60,000	9,100	1	10	Comminutors	-	-	-	-
Stirling	25,000	11,400	5	100	Screens (>35)	Maceration	Return to Flow	-	Macerator wear
Stoke	46,200	12,500	13	0	Screens (19)	-	Burial	0.016	Mechanical
Yeovil	27,000	11,300	20	0.7	Screens (25) Comminutors	- -	Burial -	0.032	-

Table 3.1 (continued) Summary of Results from Questionnaire on Screening Practice

Population served - less than 20,000

Sewage works name	Population served	D.W.F. (m^3/d)	Percentage trade waste in raw sewage (% of D.W.F.)	Percentage pumped flow	Screening practice: Screens (screen openings in mm) or comminutors	Screening practice: Screenings treatment	Screening practice: Screenings disposal	Volume of screenings (m^3/ 1000 head.d)	Problems encountered or comments
Abergavenny	14,750	3,300	10	4.5	Screens (25)	-	Tipped	0.039	Mechanical
Ashton Keynes	1,000	985	0		Comminutors	-	-	-	-
Bourton	3,700	600	0		Comminutors	-	-	-	-
Carmarthen	12,900	1,030	Trace	100	Comminutors	-	-	-	-
Carterton	13,400	3,860	60		Screens (25)	Maceration	Return to Flow	-	-
Cirencester	20,000	4,950	2		Screens(>35)	-	Burial	-	-
Cowdenbeath	11,000	4,550	8	0	Screens (25)	-	Burial	0.012	Obsolete plant
Faringdon	3,930	590	0		Screens (25)	-	Burial	-	-
Forfar	10,600	3,360	43	0	Comminutors	-	-	-	-
Frome	14,700	5,000.	7	0	Comminutors	-	-	-	'Balling up'
Grangemouth	15,000	9,300	5	100	Screens (20)	-	Burial	-	-
Highworth	6,400	1,050	0		Screens(20-35)	-	To land with sludge	-	-
Pontardawe	16,000	3,900	5	0	Screens (25)	Washed	Tipped		Screenings hand fed
Pudsey	10,000	1,365	Trace	0	Comminutors	-	-	-	-
Truro	14,500	4,320	Trace	0	Screens (19)	-	Burial	0.039	-
Witney	13,500	2,510	44		Screens (24)	-	Burial	0.013	Hand raked screen. 'Balling up' when comminutor used.
Wroughton	8,100	2,160	5		Screens(20-35)	-	Burial	-	-

Notes :

i) "Storm screenings" refers to overloading of the screening installation at times of storm.

ii) "Balling up" refers to problems with subsequent treatment processes resulting from fibrous material matting together downstream of the macerator or comminutor.

iii) Volumes of screenings are average values, based on data received in various formats and converted to the units used in the table.

iv) Populations are those given in the "Directory of Municipal Wastewater Treatment Plants" published by the Institute of Water Pollution Control, 1972.

Name of sewage works	Population served	D.W.F. (10^3 m^3/d)	Screen openings (mm)							Average screenings volume (m^3/d)	Maximum screenings volume (m^3/d)	Percentage trade effluent in raw sewage
			5	12	19	22	25	38	65-75			
Bolton	248 000	82.3					0.013			3.13	6.26	26
Bristol	300 000	140			0.007					2		9
Crossness	1 600 000	500					0.005			7.86	12.9	8
Deephams	640 000	178							0.001	0.72		11
Riverside	350 000	86.8							0.007	2.4		24
Manchester	800 000	310		0.008						6	42	38
Nottingham	456 386	146				0.007				3.4		30
Brockhurst	83 300	28							0.010	0.86		21
Cheltenham	95 000	27.3			0.011					1	3	21
Chertsey	80 000	18.2			0.009					0.75		5
Chesterfield	81 000	16.2			0.02					2.1		23
Dewsbury	110 000	42.5	0.02							2.25		14
Kew	90 000	34.4			0.008					0.74	1.02	5
Luton	117 000	37.3						0.017		2		27
Northampton	130 000	51			0.023					3		15
Swindon	125 000	26			0.018					2.27		15
Altrincham	38 000	10.6				0.008				0.3	1.0	-
Brighouse	46 000	16.9					0.02			1.3		9
Crewe	52 500	18.2			0.006					0.3		18
Kettering	47 000	13						0.028		1.32		3
Stoke	46 116	10.2			0.016					0.76		13
Yeovil	27 000	10.2					0.032			0.87		20
Abergavenny	14 750	3.3					0.039			0.57		10
Cowdenbeath	11 000	4.1					0.012			0.13		8
Redbridge	30 000	5.6					0.007			0.21		0
Truro	14 500	6.5			0.039					0.57		0
Witney	13 500	2.5					0.013			0.18		44
Average volume			0.02	0.008	0.016	0.008	0.018	0.023	0.006			

(d) only four of the works surveyed have installed fine screens (opening size $\leqslant$ 10mm)

3.1.3 Maceration

The results of the questionnaire survey are summarised in Table 3.3. This reveals that 31% of the works surveyed macerate screenings and of these about half report problems; the largest single problem being 'balling-up' of macerated screenings most probably due to inadequate maceration.

3.1.4 Communition

The results of the questionnaire survey are summarised in Table 3.4. This reveals that of the works surveyed, about 30% have installed comminutors of which about half reported operation problems. The most widespread problem is shown to be 'balling-up' of rags and similar material following comminution. Two of the works surveyed have screens installed downstream of the comminutors and two more are at sea outfalls where comminution was the only treatment given to the sewage prior to discharge.

The survey shows a definite problem of 'balling-up' in connection with the use of comminutors although it is pertinent to point out that the only installation where the new narrow slot comminutors have been fitted, has not been in operation long enough to assess results.

3.1.5 Pressing

Of the works surveyed only five had screenings presses and installation at two additional works was in progress. At one of the five works a press is employed dewatering screenings from a sludge screen.

3.1.6 Washing

One one works covered by the survey had a screeningswasher installed. This did not work satisfactorily and was considered inefficient. The manual feed was also an objectionable job due to the presence of abbattoir wastes in the screenings.

Table 3.3 Summary of Survey Results on Maceration.

Size of works (population served)	Number surveyed	Number macerating screenings	Number with no problems	Number with problems		
				'Balling up'	Maintenance/ wear/ blockages	Access to macerator
> 200,000	20	8[(a)]	2	3	3	1
200,000 - 75,000	30	9[(b)]	4[(b)]	1	4	-
75,000 - 20,000	39	15	11	2	2	-
< 20,000	17	1	1	-	-	-
Total	106	33	18	6	9	1

(a) Includes one where macerated screenings are dewatered and buried.

(b) Includes a sea outfall.

Table 3.4 Summary of Survey Results on Comminution

Size of works (population served)	Number surveyed	Number comminuting	Number with no problems	Number with problems		
				'Balling up'	Overloads at storm	Maintenance
> 200,000	20	6	1[a]	4	-	1
200,000 - 75,000	30	8[b]	2	3	1	2[b]
75,000 - 20,000	39	11	7[a]	3	1	-
< 20,000	17	6	5	1	-	-
Total	106	31	15	11	2	3

(a) Includes a sewage works with screens downstream of the comminutors.

(b) Includes two number sea outfalls.

Table 3.5 Summary of Survey Results on Landfill

Size of works (Population served)	Number surveyed	Number practising burial	Number practising tipping	Number practising to land with sludge	Percentage to land
>200,000	20	7	2	-	45
200,000 - 75,000	30	14	1	-	50
75,000 - 20,000	39	13	1	-	36
<20,000	17	7	2	1	59
Total	106	41	6	1	

3.1.7 Landfill

The questionnaire survey revealed that disposal of screenings by landfill either by burial or tipping on a local authority landfill site was the most widespread method of disposal. A total of 48 sewage works, 45% of the total, disposed of screenings in this manner and of these only two reported problems, one with rodents and the other with the transportation of the screenings. The results of the survey are presented in Table 3.5.

3.2 VISITS TO SEWAGE TREATMENT WORKS AND MANUFACTURERS

In the course of this project visits were made to certain sewage treatment works and the main manufacturers of screenings equipment, and in addition discussions were held with representatives of various Water Authorities and Consulting Engineers. The purpose was to:

(1) ascertain any operational problems encountered with the various methods of screenings; and

(2) assess current screenings practice and recent developments in screening and the handling of screenings

Visits were made to:-

BANBURY, Cherwell Pumping Station
BLACKPOOL, Manchester Square Pumping Station
BIRMINGHAM, Minworth Sewage Treatment Works
BROCKHURST Sewage Treatment Works
BURTON-ON-TRENT Sewage Treatment Works
COLESHILL Advances Wastewater Treatment Plant
DEWSBURY Sewage Treatment Works
DUKINFIELD Sewage Treatment Works
HARTLEPOOL Northern Sea Outfall
HUNSTANTON Sea Outfall
KIDDERMINSTER, Hoodbrook Pumping Station
MANCHESTER, Davyhulme Sewage Treatment Works
NORWICH Sewage Treatment Works
STOURBRIDGE Sewage Treatment Works

the following manufacturers either visited or consulted:-

Ames Crosta Babcock Limited, Heywood

F. W. Brackett &Co., Limited Colchester

Dorr-Oliver Co., Limited, Croydon

Dowson & Mason Limited, Manchester

Humboldt Wedag (GB) Limited, London

Jones & Attwood Limited, Stourbridge

Longwood Engineering Co., Limited, Huddersfield

Motherwell Bridge Engineering Limited, Motherwell

Neptune Measurement Limited, Neptune Nichols Division, Camberley

Pennwalt Limited, Camberley

Simon Rosedown Limited, Hull

Simon Hartley Limited, Stoke-on-Trent

Sinderation (Pty) Limited, Johannesburg

Vickerys Limited, London

Whitehead & Poole Limited, Radcliffe, Manchester

the following Water Authorities consulted:-

Anglian Water Authority

North West Water Authority

Severn Trent Water Authority

Southern Water Authority

Thames Water Authority

Welsh National Water Development Authority

Yorkshire Water Authority

and the following Consulting Engineers consulted:-

Balfours, London

C. H. Dobbie & Partners, London

Freeman, Fox, Braine & Partners, Cardiff

Lewis & Durivier, London

Mouchel & Partners, London

3.2.1 General

Opinions are divided not only about the type and size of screen to be used but also over the advisability of screening at all. The alternative practice of using comminutors or barminutors does not require the removal of screenings from the flow and the unpleasant disposal task is avoided. There are, however, associated problems and the use of screens can be advantageous.

Where screens are used for plant protection the actual size of the screen openings is dependent upon the size of the largest particle which may be allowed to pass, which is governed by the minimum opening in any pump, pipe fitting or piece of equipment following the screen. The present practice of using sophisticated equipment in sewage works has meant that there has been a tendency towards the use of finer screens.

The following guide lines are suggested for the choice of screen size:

Location	Minimum Dimension Across Opening (mm)
Protection of sewage pumps	100 to 150mm
Inlet works	20 to 25mm (20mm normal)

Records of one manufacturer show that for sewage works the most popular opening size was 19mm in the 1940's, 25mm in the 1950's and is now 20mm.

3.2.2 Classification of Screens

For the purpose of this project the following screen classifications have been adopted:

Screen	Minimum Dimension across Opening
Coarse	$>$ 10mm
Fine	$\leqslant$ 10mm

The division between coarse and fine screens is based on manufacturing criteria rather than performance; bar screens are not normally manufactured with openings of less than 12mm and the maximum size of opening adopted in perforated plates is normally 10mm.

The above classifications do not apply to special types of screen such as the hydraulic screen.

3.2.3 Hand Raked Screens

Hand raked screens are used at small pumping stations and on very snall treatment works, although the present tendancy is to use mechanically raked screens or comminutors. Hand raked screens are also used in by-pass channels on larger treatment works.

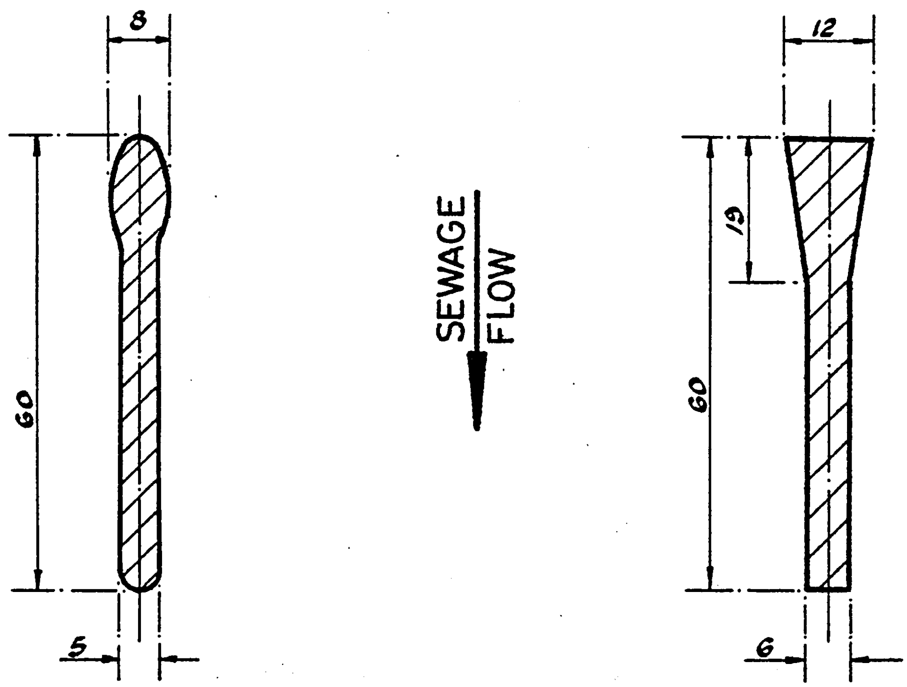
This type of screen is normally installed at an angle of about 60° to the horizontal to allow for hand raking and a perforated trough provided at the top of the screen, where the screenings may be stored temporarily for drainage. The screen bars are usually not less than 10mm thick by 50mm deep though occasionally round bars are used.

Hand raked screens are easily overloaded and may become blocked in times of storm. The regular cleaning that is required is a very unpleasant task and it is probable that this type of screen will become less common in the future.

3.2.4 Coarse Screens

3.2.4.1 The type of screen chosen for a particular application depends on such factors as:-

1. dimensions of screen channel;
2. variation and depth of flow in the channel;
3. volume and type of solids in the sewage and the nature of screenings to be removed;
4. the extend of automation or manual labour that will be provided



Brackett- Geiger Profiled Bar   Tapered and Parallel Bar

Fig. 3.1 Cross Sections of a Profiled Bar and a Tapered and Parallel Bar (dimensions in mm)

The various sections of screen bar generally available are:-

1. tapered - generally 60mm deep, tapering from 12mm to 6mm;

2. parallel

3. tapered and parallel - 60mm deep tapering from 12mm to 6mm over the first 19mm, and then parallel over the rest of the section (Figure 3.1)

4. round

5. profiled bar - these bars, such as the Brackett-Geiger, are designed to give minimum resistance to flow (Figure 3.1)

The tapered type of bar is most commonly used and is the easiest to rake. With tapered bars the tines of the rakes need only penetrate half way into the opening of the screen but with parallel bars complete penetration must take place to effect efficient cleaning, and because of this parallel bar screens tend to bind more easily than taper bar screens. The tapered and parallel bar combines the cleaning advantages of a tapered bar with ease of construction. The profiled bar has these advantages and also gives a low resistance to flow, although this bar tends to be the more expensive.

3.2.4.2 The curved bar screen (Figure 3.2) is designed for use in shallow channels of widths and depths between 1 metre and 2.5 metres. The main advantage of this type of screen is that all the working parts are above the sewage flow, thereby easing maintenance. The screen bars are curved in the vertical plane and the rake arm has a reciprocating motion which engages and cleans the screen when moving in the upward direction. On reaching the discharge point about the top of the screen the rake sweeps the screenings into a trough or onto a conveyor. The rake arm may be driven hydraulically or by an electric motor. Profiling of the rake arm is effected hydraulically or by a

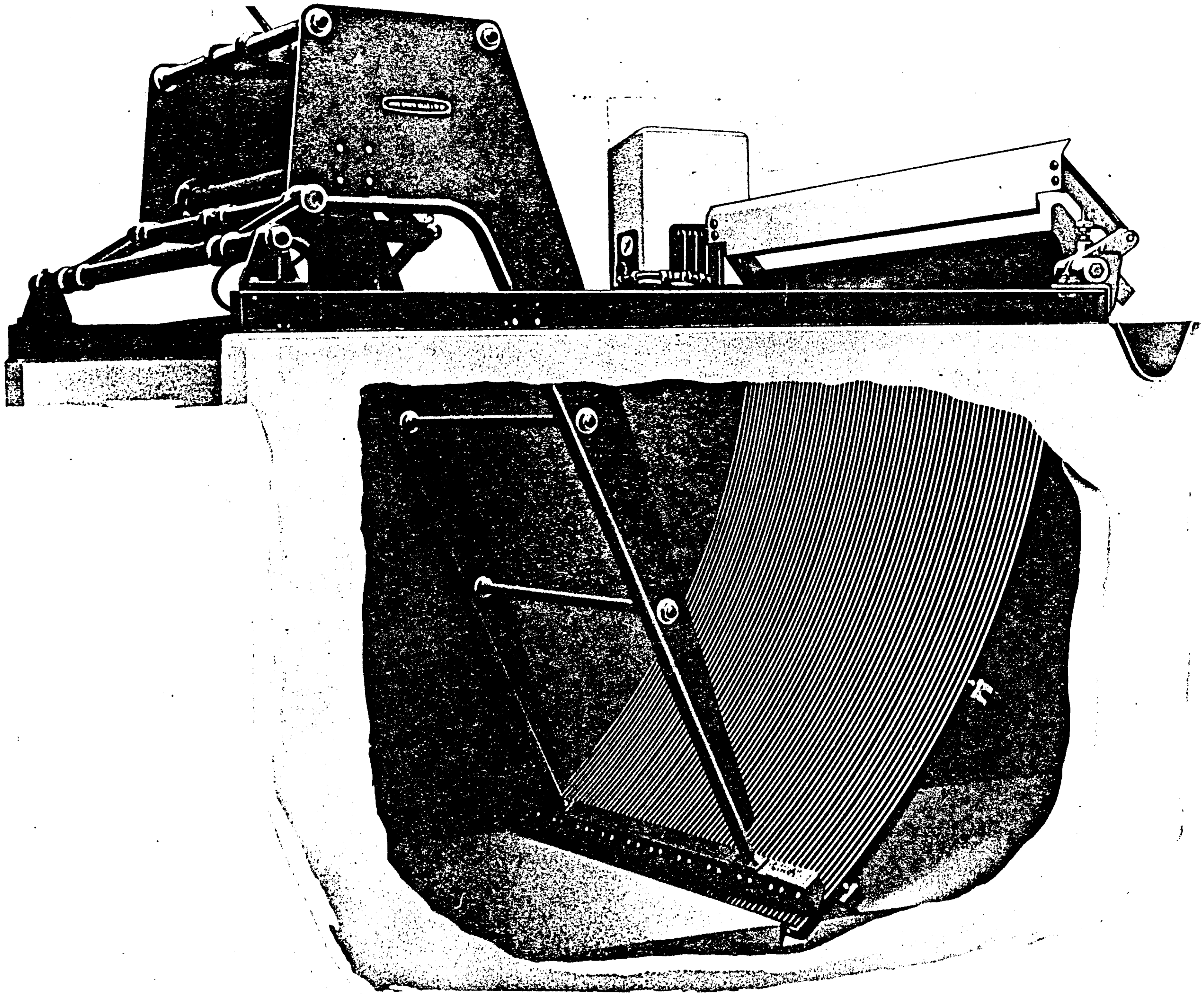


Fig. 3.2 Curved Bar Screen

spring loaded mechanism. A disadvantage is that the screenings cannot be lifted much above coping level and this should be considered when deciding upon the location of any further screenings treatment or disposal processes. The curved bar screen provided a larger area of screen per depth of flow than a straight bar screen. Manufacturers generally consider that in view of the problems associated with forming curved bars, the realistic minimum bar spacing for this type of screen, to avoid binding between bars and raking tines, is 12mm; though one manufacturer did suggest a minimum of 9mm. It was noticed at one of the works visited that considerable wear of the raking tines had occurred on a screen with 12mm spacings. Once installed, these screens have generally been found to operate efficiently.

3.2.4.3 The rotary arm screen is also constructed of curved bars but the raking mechanism describes a circular motion, engaging the screen bars at the base and maintaining contact until above top water level. The screenings are discharged to a channel or conveyor. The raking gear then either continues its circular path to re-engage with the screen at its base or comes to rest with all components above water level. This screen is suitable for installation in channels of width 0.6 to 1.5m and a maximum depth (invert to coping) of 1.5m. The operational comments for the curved bar screen are also applicable to this type of screen.

3.2.4.4 The rotating bar screen is designed to retain large solid objects which could cause damage to pumps and valves but to pass soft or fibrous material. The screen consists of hydraulically or chain driven rotating bars approximately 75mm diameter which allow soft or fibrous screenings to flow between the bars, thereby only retaining large objects which are removed periodically by hand raking. Screen openings of between 75mm and 150mm are available. This screen could be classed as a very coarse screen and is intended for use on pumping stations and small sewage works where no facilities are available for dealing with screenings or ahead of normal coarse or fine screens at a large sewage treatment works.

The first screens of this type to be installed in this country are at Banbury and Stockton-on-Tees. Inspection of the Banbury installation showed that of the 8 No. bars in the screen, 2 No. were not rotating and the remainder were rotating at varying speeds, from very slow up to about 30 rpm. The cause of this fault was not ascertainable but it did throw doubt onto the philosophy of the design as there appeared to be no difference in performance between different parts of the screen regardless of whether the bars were rotating quickly, slowly or not at all. The screen has operated satisfactorily for about 2½ years escept that on some occasions straw (a particular hazard at Banbury due to the cattle market) had blinded the screen and the operators suggested a textured or ribbed finish to the bars as an alternative to the present smooth rubber finish.

3.2.4.5 The grab screen is a front raked straight bar screen primarily designed for application in deep channels. The screen is cleaned by a raking carriage which moves up the vertical screen. Screenings are discharged above the top of the screen bars and usually above ground level. The raking carriage which may be electrically or hydraulically driven, may be operated intermittently or continuously. This type of screen is very robust, can be used under heavy duty conditions, and there is no limit to the height to which the screenings can be lifted. However, there is a tendency for the rake to repeatedly pass over lodged particles. The screen is usually aligned vertically but may be inclined at approximately 70^{o} to the horizontal for channels up to 4m deep. The inclined screen has the advantage that the screenings hopper can be positioned under the line of the raking carriage, thus dispensing with the need for a hinged discharge plate. Furthermore, it has been shown at one of the works visited that alteration of a screen from vertical to inclined has helped to stop screenings becoming lodged between the bars. In very deep channels a vertical screen would probably be more suitable since an inclined screen would require more space. If screenings discharge plates are used, one manufacturer recommended that they are set at a minimum of 60^{o} to the horizontal in order to be self cleaning. Whilst another suggested that with bar spacings of 100mm and greater twin raking tines should be used for each space.

3.2.4.6 The continuous screen (Figure 3.5) is a type of screen which has been in service for many years in this country although is now seldomly installed in new works. It is an inclined front raked screen suitable for channels up to 25m deep. Rakes are rigidly mounted on a continuous moving chain resulting in thorough cleaning of the top and sides of the bars. Increased screen cleaning can be effected by increasing the speed of the chain or by the addition of further rakes to the chain. The main disadvantage with this type of screen is the presence of moving parts below flow level resulting in wear. The use of specially sealed bearings has reduced wear but maintenance is nevertheless important. Also unlike the grab screen, this type of screening mechanism will not profile round objects jammed in the screen.

3.2.4.7 The back raked screen (Figure 3.6) has bars extending to the full depth of the channel, and may be vertical or slightly inclined. There are no intermediate bar supports, and therefore large section bars are required for deep screens in order to avoid distortion at high flows. Two types of raking mechanisms may be fitted to this screen: the first has raking tines fitted to continuous chains, the speed of which can be varied to suit conditions: and the second is a grab rake with a reciprocating action. The screen is cleaned by the upward travel of the rake, which is situated on the downstream side of the screen, facing into the sewage flow. This method does not push solids against or through the bars. With the continuously raked inclined screen, the bars are usually round, fixed at the bottom only, and supported on the raking tines. This allows the bars to move, solids measuring up to two times the nominal clear spacing between bars may pass through, problems also occur with the cleaning of the bars at the end of the raking cycle. A further problem is that because the raking

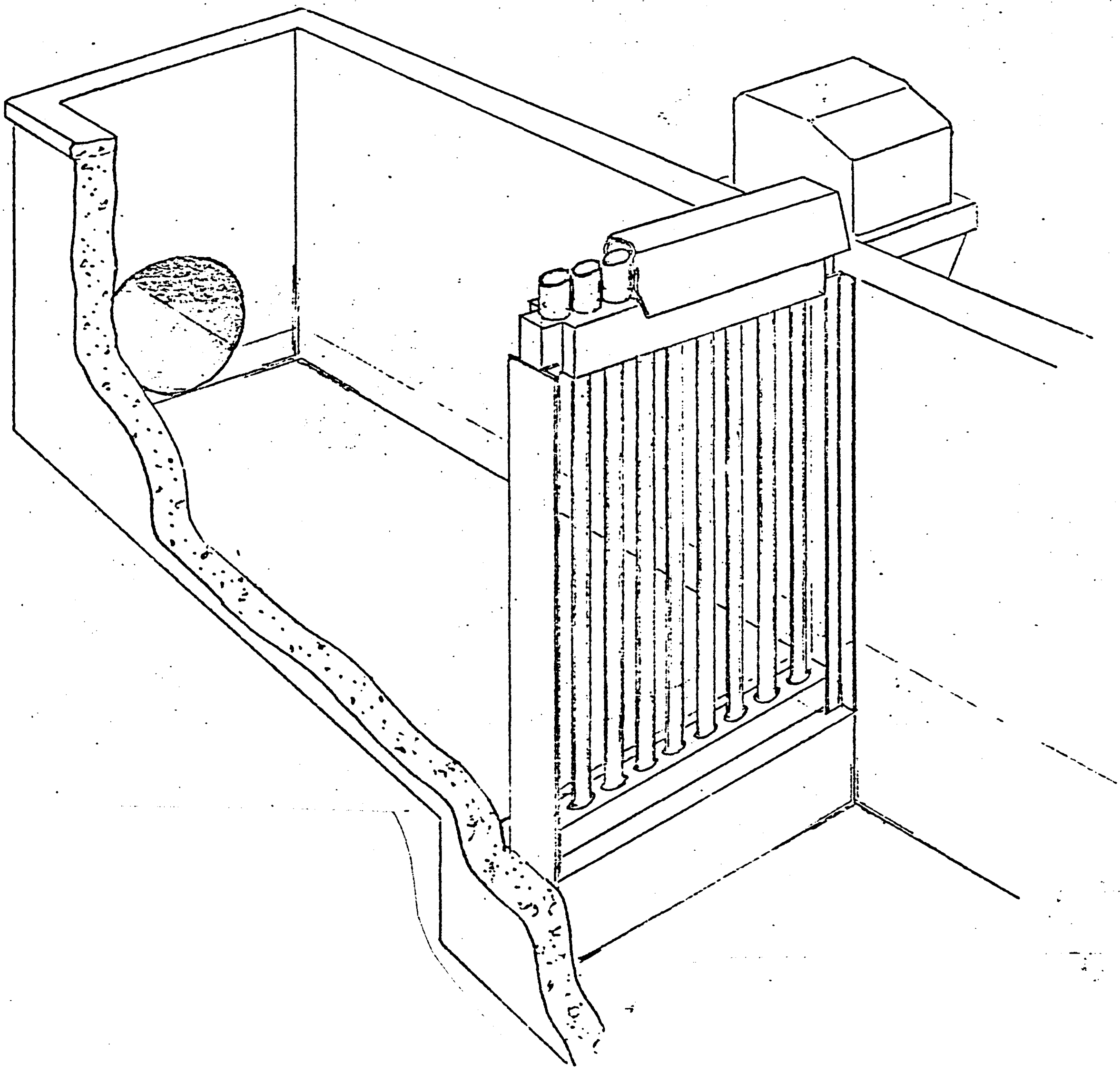


Fig. 3.3 Rotating Bar Screen

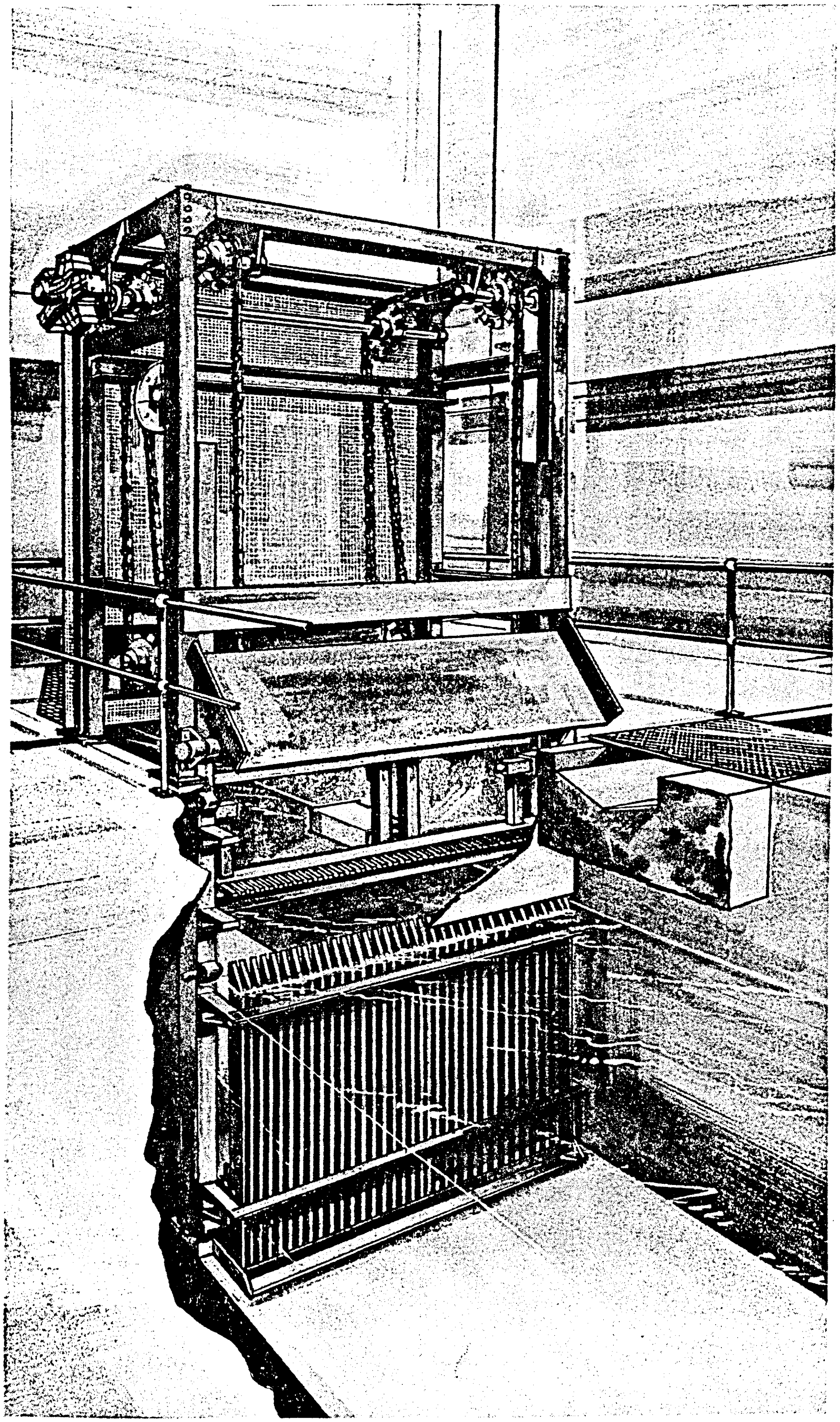


Fig. 3.4 Grab Screen

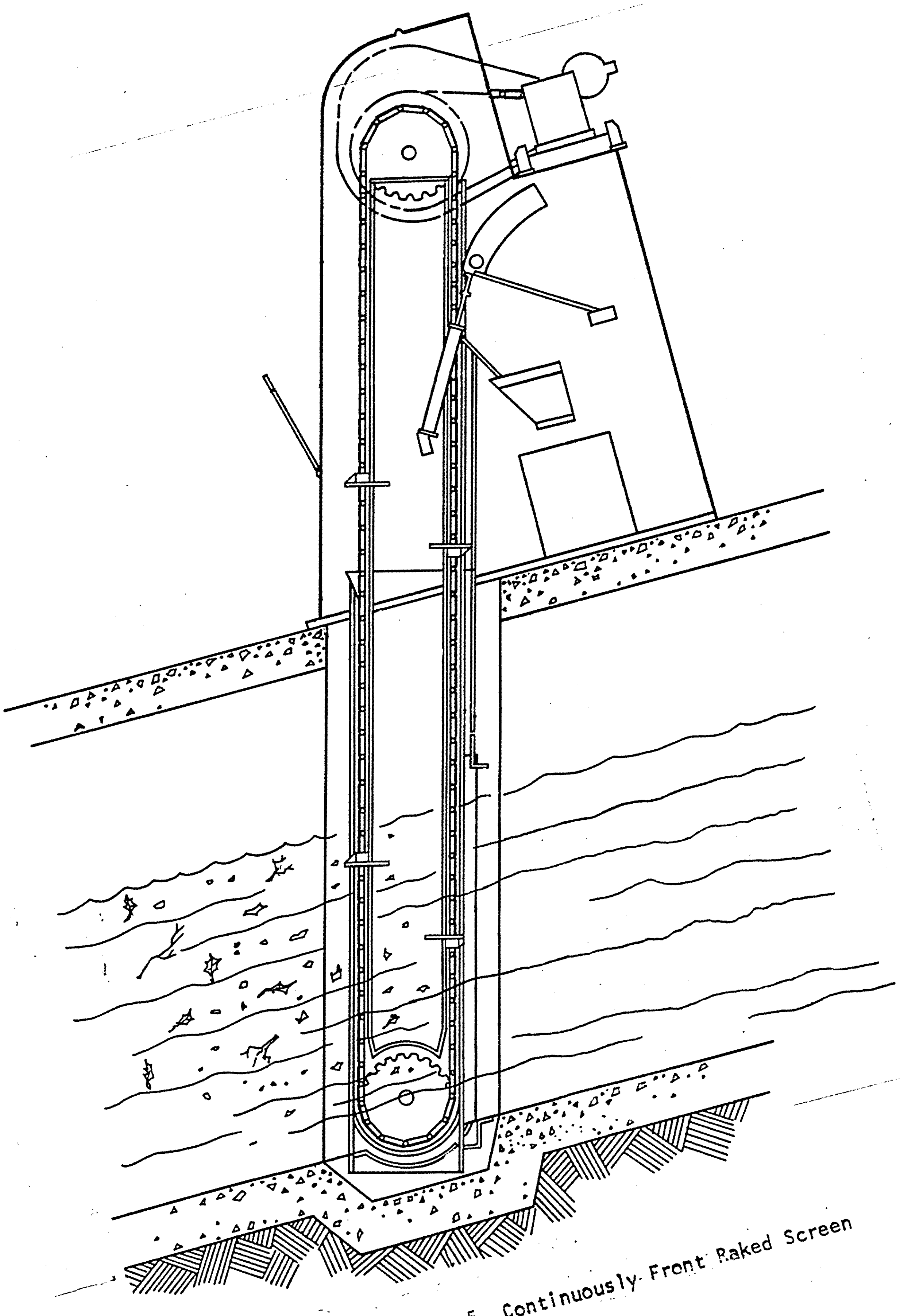


Fig. 3.5 Continuously Front Raked Screen

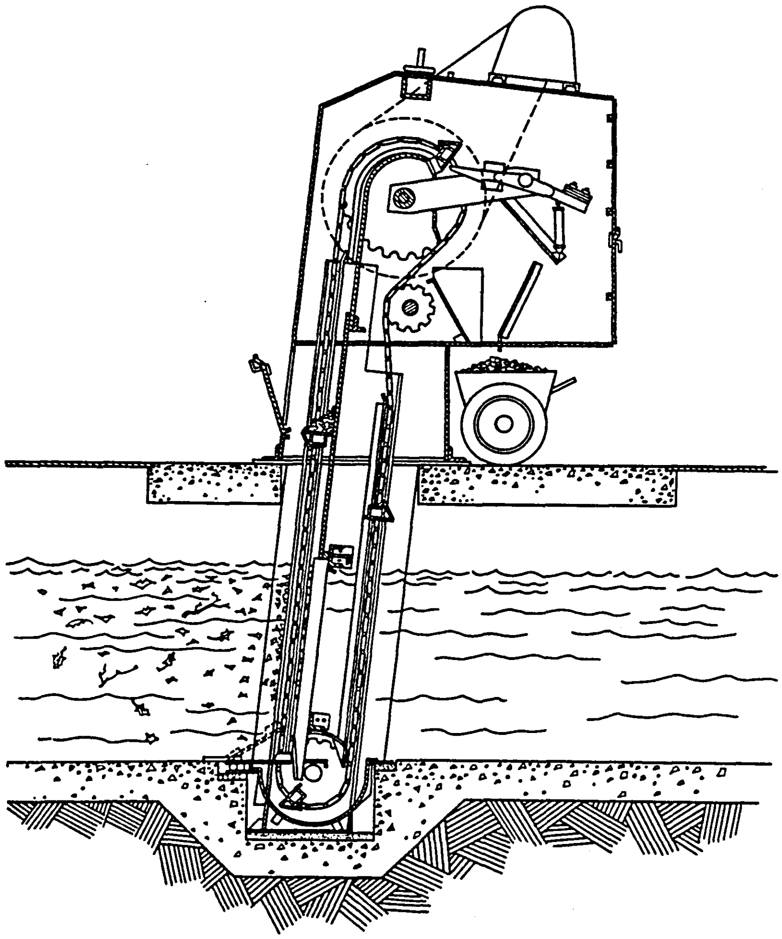


Fig. 3.6 Continuously Back Raked Screen

mechanism returns behind the screen, any solids remaining on the tines are returned to the sewage behind the screen and are therefore washed off into the screened flow. This may be minimised by careful adjustment of rake cleaning blades. This screen is not in common use in the UK. Where they have been installed it is often as a very coarse screen of openings 100 to 150mm, preceeding a finer screen.

3.2.5 Fine Screens

3.2.5.1 Fine screens generally have openings between 5 and 10mm. The principle reason for the use of fine screens at sewage treatment works is to eliminate subsequent treatment difficulties caused by the presence of certain trade effluents in the raw sewage. For instance, at Dewsbury and Blackburn fine screens have been installed to eliminate the possibility of fibres from the textile industry causing scum formation in the sludge digesters. In other cases, the presence of cannery wastes, suspended nylon and wool fluff from the carpet industry and feathers from poultry processing in the raw sewage have all caused the installation of fine screens. In one case fine screens were installed to avoid the necessity for sludge screening or maceration prior to sludge pressing. Storm sewage at Havant is treated prior to discharge to the harbour by passing the flow through drum screens fitted with 6.4mm openings. This system has been found to operate satisfactorily, with the screens requiring only occasional cleaning with a brush.

3.2.5.2 Cup screens are cylindrical screens (Figure 3.7) having sewage entering through one or both ends, depending on whether single or double entry. The sewage then flows outwards through the screening elements in the periphery. The cylinder is supported on an axial shaft running in bearings designed to take both radial loads and axial thrust. On the inside of the periphery, buckets elevate debris from the unscreened sewage and this together with the screenings retained by the screening mesh, is discharged into a hopper by gravity and by the flushing action of water jets on the outside of the screen. Single entry screens are manufactured up to 9m diameter and double entry up to 20m diameter.

3.2.5.3 Drum screens differ from cup screens in that sewage flows radially into the screen and the screened sewage flows away in an axial direction (Figure 3.8). Gross solids collect on the outer face of the drum, and are carried down with the drum as it rotates. They are then washed off the surface of the drum on the downstream side by the cascading action of the sewage carried up by the rising side of the drum. This type of screen is self cleansing and in normal circumstances requires little brushing or other cleaning. The screenings collect in a sump where they are normally removed by a macerator/pump. This type of screen is available in sizes from 0.915m diameter upto 4.08m diameter and with throughputs of upto $3.1m^3/s$ with openings of 6.35mm.

With rotating drum or cup screens the greatest advantage is that there are few wearing parts and replacements are rarely required. A disadvantage is the higher cost of the unit engineering work entailed in constructing the screen chambers.

3.2.5.4 Disc and band screens are not commonly used in sewage treatment. Disc screens have the least favourable screening area/ diameter ratio and band screens due to their construction with moving parts below the sewage and the need for seals between individual screening plates are inherently unsuitable for use with sewage, though screens of this type are installed at Blackpool.

Semi-rotary and fully rotary raking screens can be used as fine screens by replacement of the normal screen bars with a perforated plate and the tines with a rubber squeegee or brush.

It has been found with the semi-rotary screen that manual cleaning at the rear of the screen is necessary at least once a week. High pressure water has been tried for this purpose but has been found unsuccessful.

It is also possible to obtain straight inclined screens fitted with a perforated mesh instead of bars. A screen of this type, with the screening plate set at an angle of 30^{o} to the horizontal and having 25mm by 6mm slots is installed at a works in South Wales. The

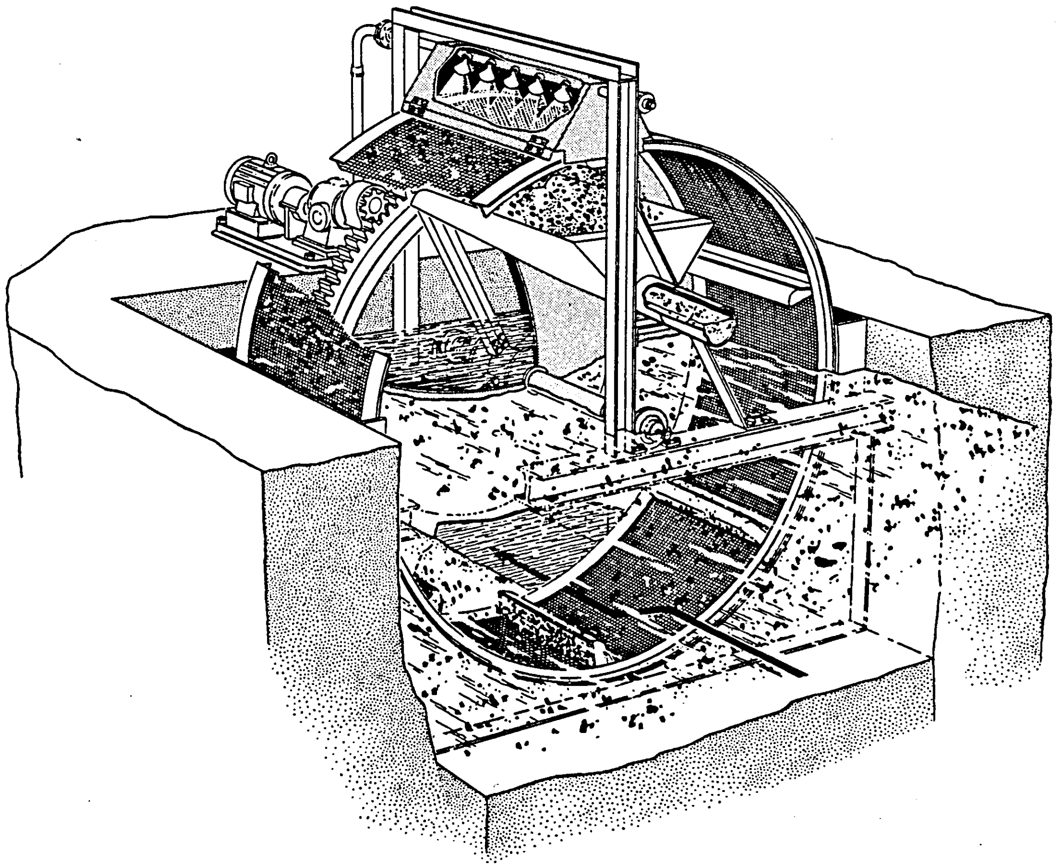


Fig. 3.7 Cup Screen

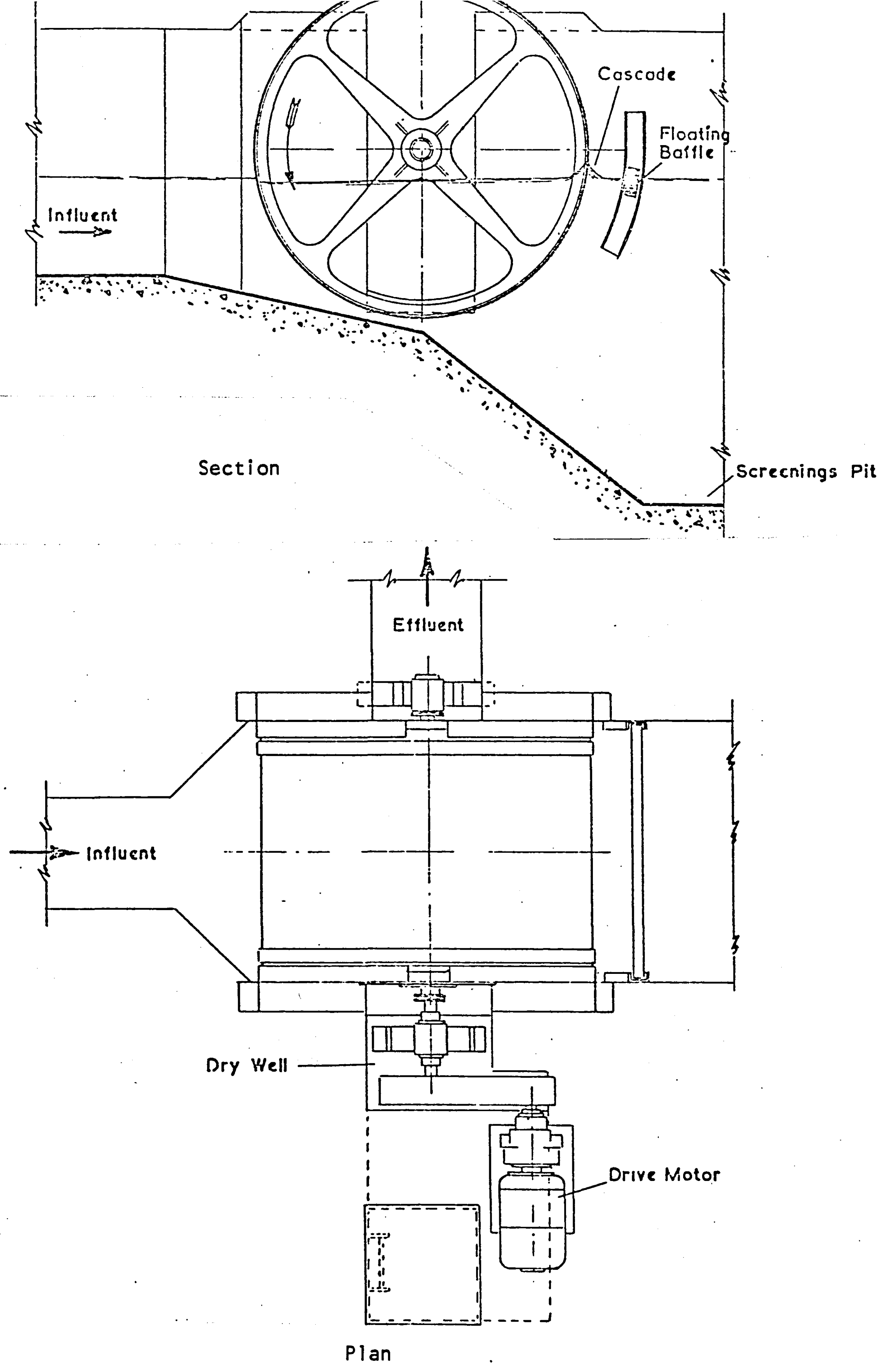


Fig. 3.8 Drum Screen

unit is positioned downstream of comminutors and ahead of a biological roughing filter. Operating experience at present is limited.

3.2.5.5 The principal problem with fine screens is clogging, the weaving of fibrous materials in and out of the screen openings leading to eventual total blockage of the screen. This effect was reported by Allen[6] in 1915 and the fact that modern installations frequently suffer from this same problem shows that little progress has been made in the intervening period. Investigation has revealed that some fine screen installations remain free from clogging and are washed easily whereas others clog frequently. Of the 15 installations visited or contacted during this investigation, eight reported clogging to some degree. No basic research into the mechanism of clogging is known and comparison of the various installations surveyed does not reveal any obvious explanation of the clogging phenomenon. It has been suggested that the smaller the openings are, the smaller is the problem of clogging. This agrees with the findings of Allen who reported experiments carried out in Germany, stating that 10mm openings clogged more readily than smaller openings. Nebolsine et al[138] reported that a screen of 6.4mm openings readily clogged wheteas screens with 0.84 and 0.42mm openings did not.

Mechanical cleaning brushes are frequently fitted to rotary cup screens but it is pertinent to note that brushes are not fitted to rotary drum screens and problems with clogging on this type of screen have not been located. Present practice is to use water for screen cleaning, which can be final effluent, screened sewage or mains water. Nozzles on the backwash jets are usually fan shaped for efficient operation. The use of screened or settled sewage for backwashing may cause blockages of the jets.

The peripheral speeds of rotary screens range between 2m/min and 38.4m/min. It is common for screens to be dual speed and screens have been installed with three speeds.

Perforated plates both punched and drilled are generally used for the screen. The percentage free area of a screen varies according to the opening size but is not usually greater than 56%. Screens are normally manufactured from galvanised steel although stainless steel and PVC have been used successfully.

3.2.6 Special Screens

The Bauer hydrasieve is a development of the sidehill screen and is intended to replace bar screens, primary sedimentation tanks and grit removal devices. The sewage is delivered to a head box above the screen from where it flows over a weir and cascades down the face of the screen. The screen plate is made up from horizontal wedge shaped stainless steel bars, and is set at three distinct angles of 25°, 35° and 45° to the vertical. Screened sewage flows through the screen whilst the solids travel down the face of the screen and are discharged at the bottom to a channel or conveyor. A 1.5mm bar opening is common for sewage applications. The hydrasieve has no moving parts and is therefore relatively maintenance free apart from occasional washing down with a steam jet or high pressure hose to remove fat and grease. The frequency of this cleaning depends on the nature of the sewage. A hydrasieve installed at Coleshill was inspected and found to work satisfactorily though the screenings were not representative of the sewage having passed through a small pump prior to screening.

The Dorr Oliver DSM screen is very similar to the Bauer hydrasieve but in this country it is only marketed as part of a patented system for the maceration and dewatering of screenings.

3.2.7 General Design Parameters

The design of a screen for a particular application should take into account the following parameters:

1. Depth of flow - the depth of flow through the screen may be calculated by considering the hydraulic conditions downstream of the screen (i.e. levels of grit channels and flumes) and taking account of dry weather and peak flow rates. The invert level of the screen may be set slightly lower or the same as the level of the incoming sewer.

2. Velocity of flow - the velocity of flow through the screen bars is commonly limited to a maximum of 0.6 m/s for flows of up to three times dry weather flow (DWF) and to 1 m/s for flows above 3 DWF. For flows greater than 1 m/s there is a tendency for screenings to be forced through the screen bars resulting in an excessive head differential across the screen. Minimum flow should be limited to 0.45 m/s in order to avoid deposition of grit.

3. Bar spacing - this is chosen according to the degree of screening required and depends on the maximum size solids which need to be removed in order to protect plant in the subsequent treatment processes. Due consideration should be taken of the nature of solids produced by any trade waste sources.

4. Width of screen channel - for screen channel, width W, the following formula may be applied:

$$W = \left(\frac{F}{V \times D}\right)\left(\frac{B + S}{S}\right) + C$$

Where F = max. flow rate, m^3/s

V = velocity of flow through screen bars at max. flow rate, m/s

D = depth of flow, through screen bars at max. flow rate, m

B = width of one screen bar, mm

S = space between screen bars, mm

C = allowance for width of side frame, m

It is normal practice to install a second screen for use as standby and to provide a by-pass channel in case of screen failure. It is also advisable to provide penstocks upstream and downstream of the screens in order to isolate a screen from the flow to allow access for maintenance.

5. Volume of screenings removed and operation time cyles - these obviously depend on the type and size of screen, the finer the screen the more frequent the screen has to be raked. As a general guide, a standard type of rake can be considered to have a carrying capacity of 8 litres of screenings per metre width of screen.

6. Head loss - This is not normally calculated since the head loss is small for a clean screen. However, it is normal practice to limit the head loss across the screen just prior to being raked to 150mm.

3.2.8 Installation

It is generally considered that screening installations should preferably be covered in order to protect mechanical and electrical equipment and lower the possibility of the freezing of water lines and sparge channels.

Despite trade effluent agreements volatile and inflammable liquids are sometimes discharged to sewers. Volatilisation of these liquids may cause poisonous or potentially explosive atmospheres in the sewer or the screenings chamber. If there is a likelihood of this occurring it may be necessary to consider explosion proof construction of the screening building, forced ventilation of the screening building, or ventilation of the incoming sewer. Due to the continuous reintroduction of foul sewer air and its high vapour content it is difficult to obtain an ideal ventilation system in the screenings chamber, however, the practice of pressurising the chamber, thus providing a positive displacement of the air, seems to be the most successful.

High pressure wash down facilities should be provided for the cleaning of equipment prior to maintenance or for aiding in the removal of blockages from the screen. Normal water mains pressure hoses are not considered to have sufficient pressure.

In order to resist the high moisture contents of screening chamber atmospheres, anti-condensation (heated) motors are usually used.

Maintenance of the screens is vitally important if breakdowns are to be avoided. A maintenance programme is necessary which specifies the work to be carried out and its frequency. Regular maintenance would consist of the greasing of moving parts, the clearing of lodged solids, and the checking for failure of any of the mechanical and electrical parts. If two screens are available they should be used alternately.

The current methods available for the timing of raking mechanisms are the timeswitch and floatswitch. It is common to use a timeswitch for normal operation and to use a floatswitch situated upstream of the screen. This overrides the timeswitch in storm conditions or in the event of screen blockage. The float for the floatswitch is usually in an enclosed tube to prevent fouling from rags and solids.

3.2.9 Treatment of Screenings

3.2.9.1 Maceration is the reduction in size of screenings usually used to prevent their causing damage to subsequent treatment plant on return to the sewage flow. If macerators are not properly maintained, resulting in inadequate maceration of solids, problems may occur in subsequent treatment processes due to 'balling-up' of rags and similar material. The macerator discharge point should be located in front of the screen, thereby allowing only completely macerated screenings to pass for further treatment. There are three basic types of macerator and each can be installed in a variety of ways.

(a) Cutter Type of Macerator

Maceration is accomplished in two stages; first between a stationary cutting blade and the inlet edges of rotating impeller blades, where the large solids are reduced in size to pass the impeller blades and second between the outlet edges of the cutting impeller and a fixed grid. Macerated solids can be discharged against hydraulic heads of up to two metres. The level of the bottom of the macerator well should be below the inlet level to the macerator so that hard heavy objects such as stones and metal may settle and be prevented from entering the macerator. These objects can then be periodically removed from the sump. Provision should be made for periodic inspection of the cutting blades so that they may be replaced or resharpened when necessary.

Throughput of this type of macerator varies between 1.0 and $4.7m^3/h$ for screenings of 80% moisture content, although the machine's size is usually decided on flow rather than volume of screenings. The screenings require to be diluted with sparge water for maceration and a dilution of 100 times has been found by experience to be successful.

(b) Hammer Type of Macerator

In this design the screenings are delivered to the macerating chamber by washwater. The macerating chamber consists of a fixed slotted cage inside of which a hammer rotates. Stones and other heavy objects fall to the bottom of the maceration chamber while screenings collect on the walls of the slotted cage and are reduced in size by the action of the hammer against the sides of this cage. Unlike the cutting macerator this machine is self sharpening. Throughput is usually similar to the cutter type of macerator and is based on flow rather than volume of screenings.

(c) Prebreaker

A prebreaker (originally designed for the animal by-products industry) has been used successfully to macerate screenings prior to pressing in a screenings press. The advantage of this machine is that due to its rugged construction, it can handle directly screenings of about 90% moisture content without any dilution with water. At this installation a permanent magnet has been fixed in the feed chute to extract metal objects from the screenings, the unit is 300mm diameter has a 26 kW motor and will handle about 2 tonnes/h of screenings.

It is considered that maceration can be an adequate method of treating screenings, particularly at works serving small populations provided that the macerators are regularly maintained and that the macerated screenings are not expected to cause any problems with the sludge handling and disposal. With the increasing amount of non-biodegradable matter in raw sewage, problems occur with the build-up of inert materials in the soil from macerated screenings where the sludge is disposed of to land. It is suggested that to help reduce the likelihood of 'balling-up', the distance from the screens to the primary tanks should be kept to a minimum.

Although macerators provide a hygenic and aesthetically suitable method of dealing with screenings, maceration is in itself only a partial treatment process. The problem of the removal of screenings at the works inlet is eliminated but difficulties may occur in subsequent treatment processes, in particular with sludge processing.

3.2.9.2 The main benefit of comminution is that the screenings are shredded without removal from the sewage, thereby eliminating the need for their collection and disposal. The two principle types are the barminutor and the comminutor.

A barminutor consists of a bar screen fitted with a cutting device, which consists of a combined rake and rotating cutting unit. This sweeps vertically up and down the screen shredding material which has been retained until it has been reduced sufficiently in size to pass through the screen. The bar opening is 10mm on small units and 20mm on large units. A diagram of a comminutor is shown in Figure 3.10, a description has previously been given in Section 2.5.2 The throughputs of a standard range of comminutors are given in Table 3.6 although comminutors can be supplied to handle lower minimum flows than in this table.

The comminutor is installed in a special flow chamber necessary for proper operation, which often makes installation expensive. However, for certain sizes of comminutor, preformed asbestos cement shutters are available for forming the correct concrete shape. Head losses are usually higher than with screens, especially in the case of comminutors with narrow slots. Floating material such as corks and accumulations of fat and grease have to be removed periodically by hand.

The main disadvantage of a comminutor is that shredded rags often tend to reform into strings of 'ball-up' and cause choking in pumps and pipelines downstream of the comminutor. The use of comminutors with the narrower shorter slots should reduce the occurrence of this problem and it is always advisable to keep the distance between the comminutor and the sedimentation tank to a minimum.

It is suggested that comminuting devices are installed upstream of any grit extraction equipment. Although this will increase wear on the cutters it will result in cleaner grit and reduce the possibility of rags being caught in the grit extraction equipment. As with mechanically raked screens, some standby and by-pass facilities should be provided for maintenance purposes. Occasionally there is need to inspect the inverted syphon and provision should be made for a washout pipe and for the removal of the unit from the flow. Comminutor motors should be installed above flood level and an extension shaft fitted where necessary to achieve this.

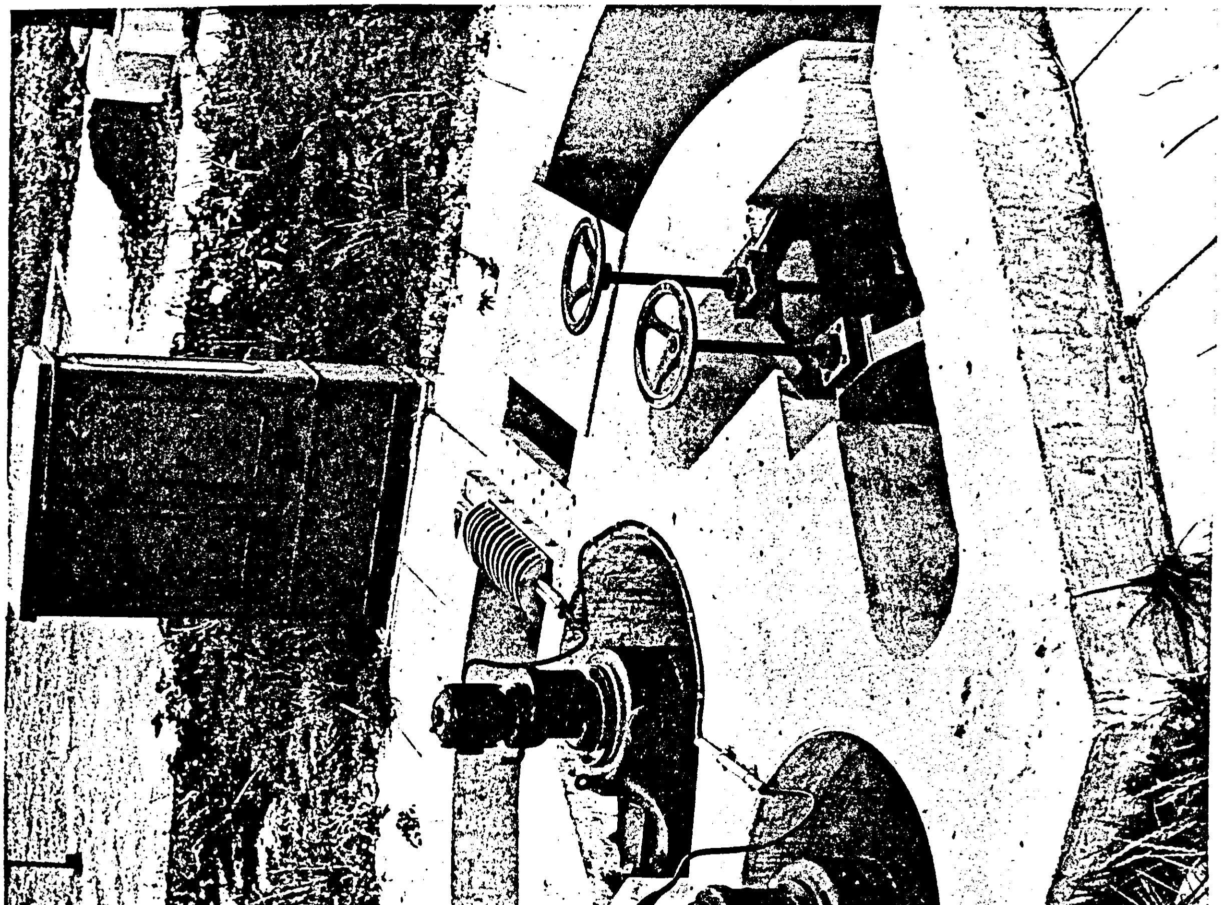


Fig. 3.9 Typical Comminutor Installation

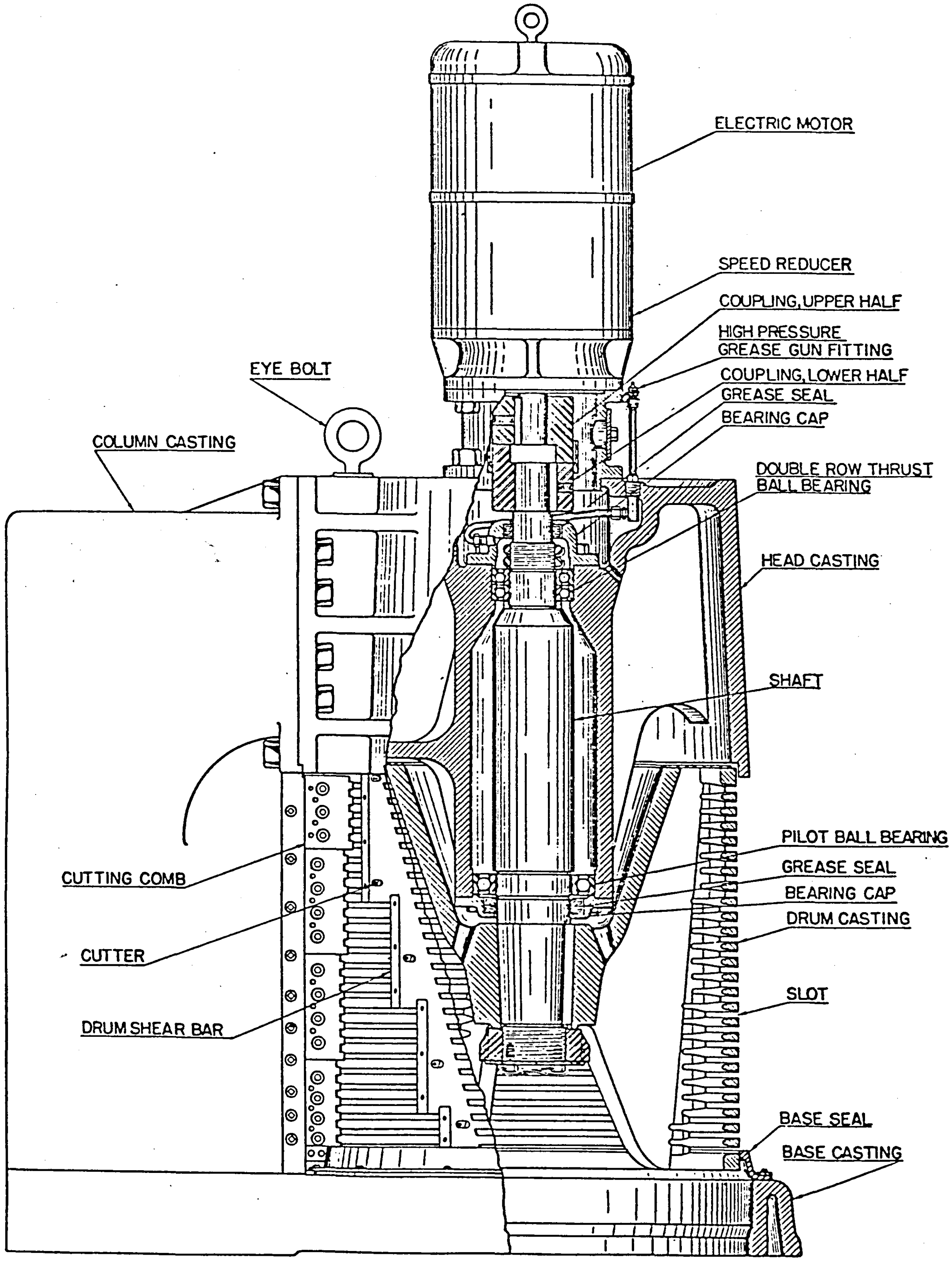


Fig. 3.10 Sectional View of a Comminutor

Table 3.6 Throughputs of Standard Comminutors

Drum diameter (mm)	Motor (kW)	Slot width (mm)	Number of slots	Drum speed (rpm)	Minimum average 12 h.day rates of flow (litre/s)	Maximum average 12 h.day rates of flow (litre/s)	Maximum Flow (litre/s)	Head loss at maximum flow (mm)
100	0.2	7	21	58	-	-	3.95	-
180	0.2	7	21	58	2.63	8.68	15.78	180
250	0.6	7	48	49	7.37	31.56	47.35	250
380	0.6	7	180	37	11.57	81.55	105	250
635	1.1	10	90	23	42.09	210	263	250
635	1.1	7	360	25	19.0	160	260	320
635	1.1	10	168	23	45.19	421	486	380
635	1.1	7	720	25	19.0	320	440	430
915	1.5	10	288	15	56.82	868	1052	380
915	1.5	7	1200	15	25.0	590	1000	700

Maintenance of comminuting devices is normally limited to replacement of teeth, combs and seals. Comminutors are now available that include a self-lifting device to facilitate maintenance. It is considered that comminutors are well suited for use on works with populations of less than 25 00, and in particular in the case of unmanned installations. Consideration should be given, as in the case of macerators, to the method of sludge disposal and the possibility of problems caused by the presence of non-biodegradable matter.

3.2.10 Pressing

Pressing is normally carried out prior to incineration, although it is sometimes used to reduce handling problems when screenings are to be disposed of off site. The degree of dewatering is largely influenced by the composition of the screenings. Fibrous materials are easily dewatered whilst materials with a high organic content such as faecal matter are only dewatered to a small degree. The basic types of screenings press are:

Ram Press
Roller Press
Screw Press
Belt Press

These presses generally cannot treat screenings of moisture content greater than 85 - 90% and consequently some prior draining is required before pressing.

(a) Ram Press

The advantages with this type of press are that the three controlling factors pressure, time and number of pressings, may be varied to obtain the optimum operating conditions and that it is able to operate with both continuous and intermittent feeding.

A ram press (Figure 3.11) comprises of a compression chamber of heavy gauge perforated steel into which screenings fall from a chute. A steel ram operates in the chamber and compresses the screenings against a pivoted sloping plate which restricts the outlet. The compression squeezes moisture out of the screenings through the perforations in the chamber walls and into a tray that surrounds the cylinder. The perforations are taper drilled. Maceration or any sorting is not required prior to pressing as objects which are only partly within the compression chamber will be sheared between the ram and the top of the chamber.

Ram presses accept screenings of a high moisture content (85 - 90%) but not waterborne screenings. Operating experience to date has been limited to screenings from coarse screens of opening size 20 to 25mm. Screenings from fine screens have a higher organic content which lowers their dewaterability. It has still to be demonstrated whether or not the ram press can deal with this latter type of material.

The throughputs of ram presses range from $0.9m^3/h$ to $6.5m^3/h$ at 85 to 90% moisture content.

A washing system can be fitted to wash the outside of the pressing chamber and the drainage system. Power is supplied by a hydraulic power pack mounted separately from the press. Operation of the press is automatic, either in sequence with the screen rake or activated by a level indicator in a screenings storage hopper.

Ram presses are capable of dewatering and pressing most materials found in screenings and of reducing the moisture content to the order of 55 to 60%. Ram presses are often used in conjunction with screenings bagging units.

One Water Authority did report problems in persuading fitters to work on ram presses following a period in operation due to their appearance.

The Screezer (Figure 3.12) developed by Jones & Attwood Limited is an adaptation of a comminutor with a small press attached. The solids are screened from the sewage by a vertical rotating cast iron drum having slots 6mm wide by 80mm long. The screenings are scraped from the surface of the drum by vertical scrapers and directed into a vertical channel trough that includes a secondary screen. A hydraulically operated foot lifts the screenings vertically to a pressing chamber at which point they are retained on horizontal tines. A horizontal ram then squeezes the screenings in a compression chamber. The pressed screenings have a moisture content of lower than 60%. The Screezer fits into a chamber of similar construction to that required for a comminutor and is capable of replacing an existing comminutor of similar size.

There are two sizes of Screezer available at present. These are capable of dealing with flows of up to 450 and 1000 l/s. It is still necessary to remove floating and large objects from the Screezer chamber by hand.

(b) Roller Press

The press (Figure 3.13) consists basically of an upper and lower roller with drive units housed inside for protection. The larger upper roller has ribs across its surface to facilitate the entry of screenings which are fed in at the rear and dewatered between it and the feed chute. The bottom roller has a smooth surface to aid the removal of screenings by a scraper. The screenings are finally pressed by a mangle action between the two rollers which, at the same time, allows large uncrushable objects to pass at either side whilst the opposite side continues its pressing action. The roller width is considerably greater than the screenings feed, thereby reducing the possibility of screenings passing through the side of the press.

The roller press reduces the moisture content of screenings from 85% to 60%. The main advantage of this type of press is that operation is continuous and avoids the need for any storage hoppers. The power requirement of a roller press is less than for a ram press of similar throughput. Roller presses are currently available in two sizes of $2.5m^3/h$ and $5m^3/h$ of wet screenings.

(c) Screw Press

In this type of press the screenings are continuously and automatically compressed by two intermeshing counter-rotating worm shafts of decreasing pitch and increasing boss diameter. This results in a progressive volume reduction of the feed material which is finally discharged as pressed cake. The filtrate is discharged through perforated screens which surround the worm shafts. These screens comprise of stainless steel inner screens with 1mm diameter perforations, stainless

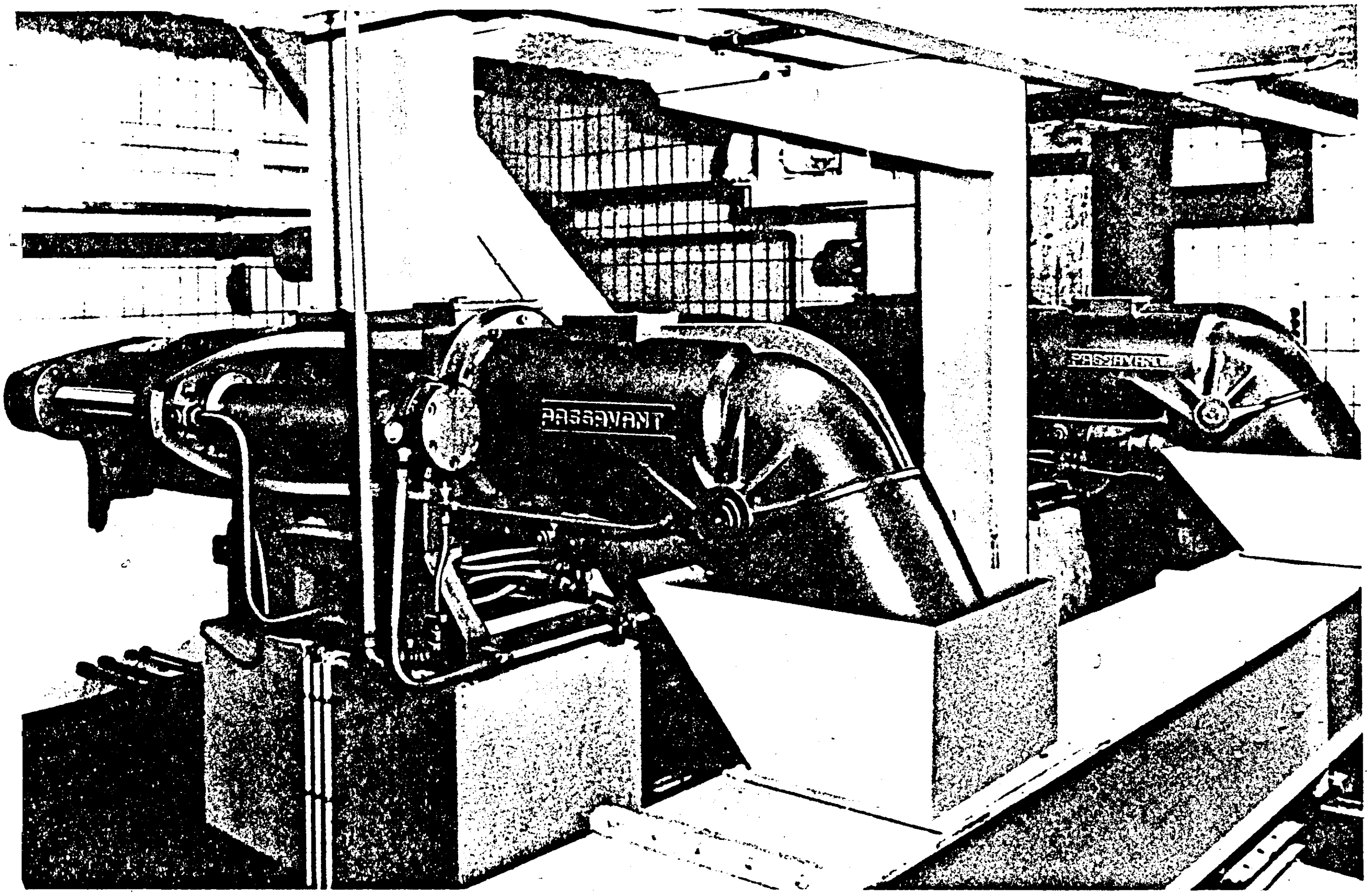


Fig. 3.11(a) Ram Press

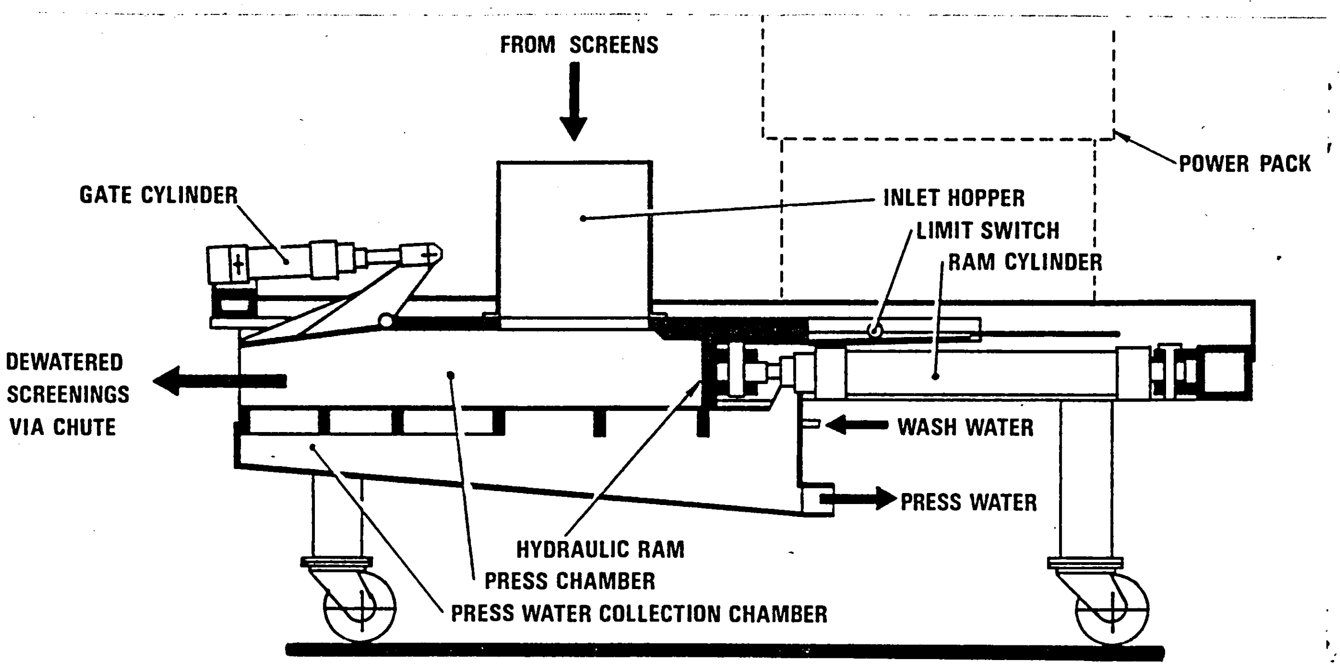


Fig.3.11(b) Ram Press

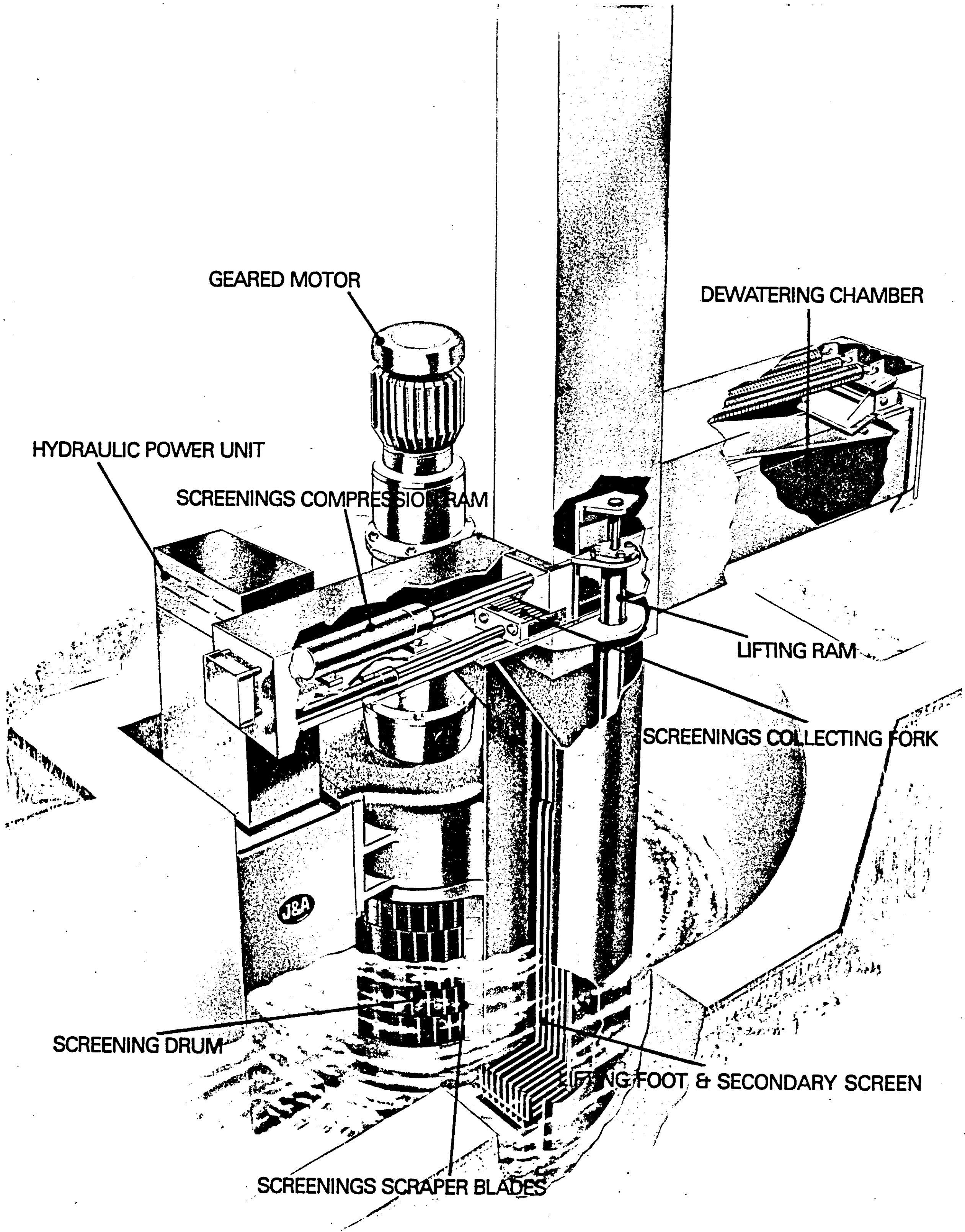


Fig. 3.12 A Jones & Attwood Limited Screezer

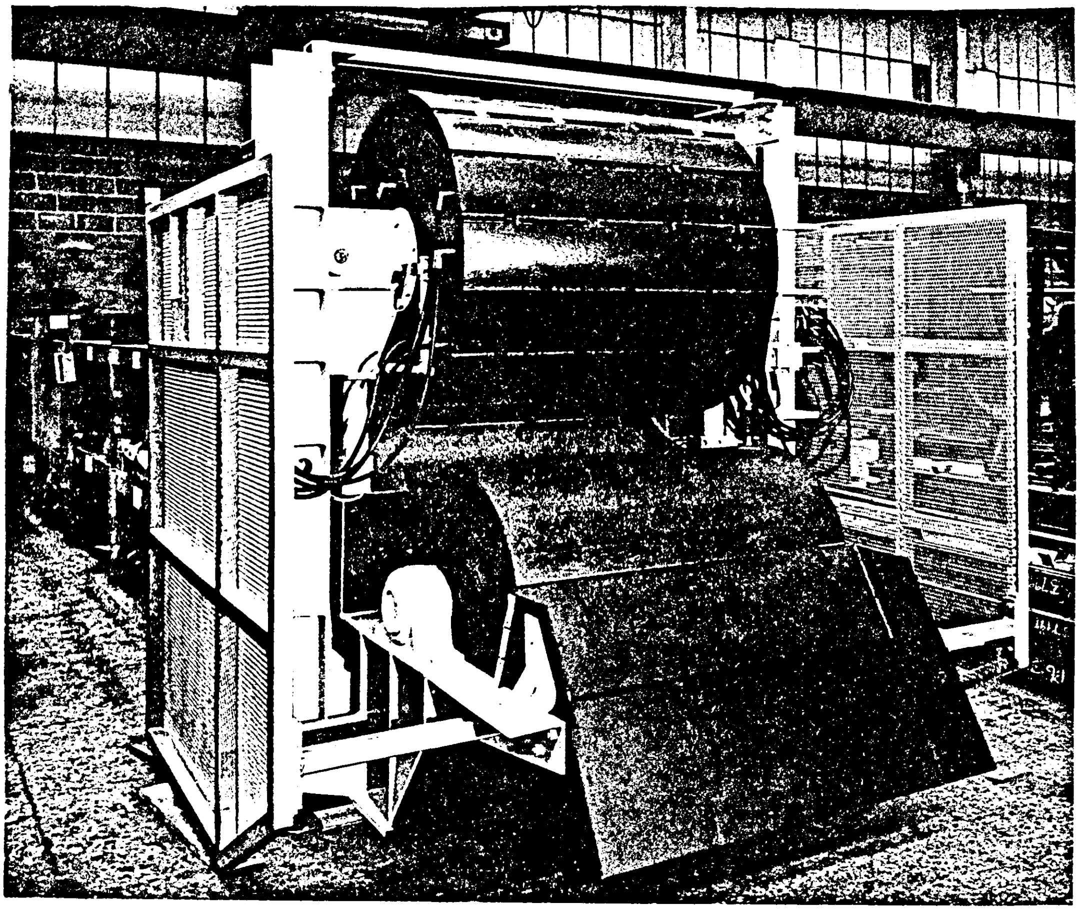


Fig. 3.13 The Brackett Geiger Roller Press

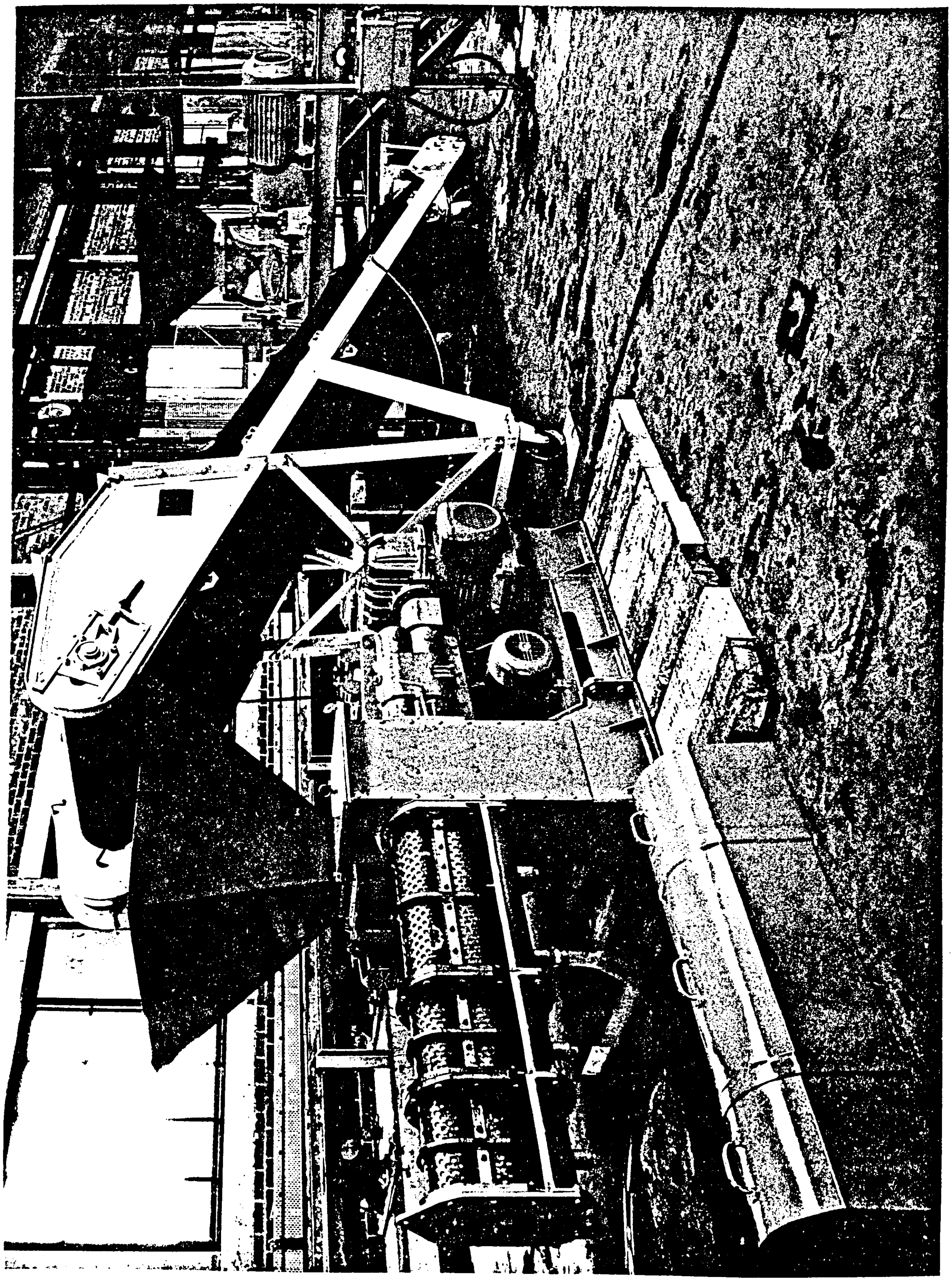


Fig. 3.14 Screw Press

steel keeper bars and mild steel backing screens with 9mm perforations. The inner screen is made from 0.9mm thick stainless steel plate. A choke plate is fitted to the discharge end. This serves the purpose of further compressing the screenings prior to discharge.

For a screw press to work efficiently there must be a continuous flow of material, and hence screenings storage is necessary. This is achieved by a metering bin alongside the press which only starts the press when the bin is full. The work shafts in the press revolve at about 10 rpm giving a retention time within the press of about two minutes. The compression ratio achieved is 4:1. The installed motor capacity on the larger presses available is about 17 kW and on the smaller 8 kW with throughputs of $2m^3/h$ and $6m^3/h$ respectively.

The screw press is unable to accept large objects and pieces of metal and therefore it is advisable to practice preseparation of ferrous metals by magnets and maceration of screenings before discharge to the metering bins.

The feed screws and press need to be checked daily for blockages and signs of damage.

The screw press is the only one which has successfully dewatered screenings from fine screens (5mm openings).

(d) Belt Press

In this type of press the screenings are dewatered between two belts, the lower belt being a dewatering conveyor belt and the upper a pressure belt.

The screenings are fed on to the dewatering belt which has a speed of 6.1m/min, and then carried between the upper pressure belt and the dewatering belt for pressing. Filtrate draining from the screenings is collected in troughs situated under the dewatering belt and thence returned to flow. Both belts have separate drive units and are cleaned by rotating nylon brushes.

The power requirement of a $1.2m^3/h$ unit is about 2 kW, and the washwater requirement is about 0.7 l/s. The press will not handle screenings containing more than 10% organics, nor should the screenings be macerated before feeding to the press. It will not accept large objects.

The principle advantages of this type of press are that it will accept waterborne screenings and also that the dewatering belt can be extended to the screens to act as a feed conveyor.

The moisture content of screenings after pressing is in the order of 65 - 70%.

Comparisons of the different types of pressed are shown in Table 3.7.

Presses reduce the volume and weight of screenings and their use may result in reduced screenings disposal costs. Presses can be operated in conjunction with bagging units to further reduce the problems associated with the handling of screenings.

There are few operating data at present for presses in the U.K., except for the ram press type, which has been performing satisfactorily. It has been pointed out that at sewage works with short sewerage systems, the lack of breakdown of solids in the sewerage system can lead to a high faecal content in the screenings thus reducing performance and hampering maintenance.

When operating as a pre-treatment stage prior to incineration the use of dried screenings results in a reduction of fuel costs, although very little saving is achieved by reducing the moisture content below the figure necessary to ensure that the screenings are autothermic. It is considered that presses should be enclosed to protect the electrical and hydraulic equipment and a high pressure washdown supply provided for washing down the equipment.

Table 3.7 Comparison of Different Types of Screenings Presses

Press	Ram	Roller	Screw	Belt
Maximum size (m^3/h)	6.5	5.0	6.0	7.0[a]
Minimum size (m^3/h)	0.9	2.5	2.0	1.2
Installed power minimum size (kW)	3.0	4.6	8.0	2.0
Coarse screenings	Yes	Yes	Yes	Yes
Fine screenings			Yes	
Waterborne screenings				Yes
Pretreatment required			Yes	
Continuous operation		Yes	Yes[b]	Yes
Storage required	Yes		Yes	
Dewatered screenings (% moisture content)	55 - 60	60	50 - 60	65 - 70

(a) Extrapolated, machine of this size not yet built.

(b) Although continuous in operation needs a uniform flow rate.

The degree to which screenings can be dewatered depends upon their composition. Textiles and fibrous materials dewater easily whereas materials with a high organic content, such as faecal matter and abattoir wastes, can only be partially dewatered.

Note should be taken of the fact that the organic content screenings increases with decreasing screen opening. With incineration this increase in moisture content generally does not present problems since the higher calorific value of the organic matter compensates for the higher moisture content. The percentage water removed can be calculated from the following formula:

$$\text{removal} = 1 - \frac{fo}{Wo} \times \frac{Wp}{fp}$$

Where:

Wo = % water content before pressing
Wp = % water content after pressing
fo = % solids content before pressing
fp = % solids content after pressing

It is possible to apply too great a pressure to screenings, which results in plasticisation of the organic matter and its discharge from the unit with the filtrate.

3.2.11 Removal of Screenings from Carrier Water

This section details methods of removal of screenings from carrier water in such instances as when sparge channels are used for conveying screenings or when fine screens are cleaned by backwashing.

The simplest method is to discharge the screenings and carrier water into a horizontal curved fine screen which allows the carrier water to drain out through the perforations. A development of this is the Parkwood Screenings Dewaterer. This is basically two fine screens in series in which screenings are pressed against the curved, perforated second screen by tension rollers. A nylon brush and a scraper discharge the screenings. The unit produces screenings of 60 to 65% moisture content. Macerated screenings, after removal of water by either of these two methods, are relatively clean looking and are less unpleasant to handle than screenings after pressing. This was noted at an inspection of a test unit at Brockhurst Sewage Works.

An alternative is the sidehill screen, described in Section 3.2.5. In this unit screenings are fed over a parabolic weir at the top of the screen and flow downwards over the surface of the curved screen. The solids are discharged from the face of the screen at the bottom while the carrier water passes through the screen. The dewatered screenings have a moisture content of about 85 to 90%.

The Vickery Consolidator consists basically of a hydraulic or sidehill screen mounted above a ram press in which the screenings fall from the face of the screen directly into a ram press. This is a small press operating at 14 cycles/minute. The operating pressure in the press is 4.13 MN/m^2 and the final moisture content of the screenings is about 65 to 70%. Minimum maintenance is required as the Consolidator has only one moving part. At Crewe a Bio Screen is used to separate screenings from carrier water and to deliver them to a ram press. The screen consists of a perforated plate inclined at an angle of 30^o to the horizontal. The screenings are raked along the screen by a number of brushes and rubber blades which are attached to a reciprocating frame. Waterbourne screenings are delivered to the base of the screen and separated screenings are discharged from the top of the screen into the ram press.

Aetempts have been made to separate screenings from carrier water by fibrating screens but these have been unsuccessful, mainly due to blinding of the screen by fibres.

3.2.12 Centrifugation

Centrifugation is a means of effecting solids/liquids separation by centrifugal force. Solids are separated from liquid by a process of accelerated sedimentation, thousands of times faster than would be obtained by settling under the force of gravity alone.

In the field of sewage treatment centrifuges are applied generally to the dewatering of sewage sludges. However, attempts have been made in the past to dewater screenings. Two types of centrifuge which have been tried are:

1. Decanter Centrifuge

This machine (Figure 3.14) consists of a conical cylindrical bowl inside which is a screw conveyor. Both rotate in the same direction although a slight differential speed between the bowl and the screw conveyor permits continuous movement of the settled solids compacted against the bowl wall. The screenings are fed into the machine by a central pipe and rotational forced propel the screenings to the periphery of the bown whilst the supernatant water spills over the weirs located in the bowl end. Throughput is controlled by a variable speed pump which feeds the screenings into the centrifuge.

2. Perforated Basket Centrifuge

This is shown in Figure 3.15. Liquid passes through the perforated bowl and a solid layer of material is retained on the bowl wall. This machine can be operated on a batch or continuous basis and is available in either a horiziontal or vertical version. For continuous operation screenings can be pumped into the machine by a central pipe. Discharge is effected by a full width rotary knife which pushes solids into an angled chute.

Messrs. Pennwalt Limited undertook some tests using a decanter centrifuge to dewater screen backwashing at Blackpool in 1975. Screenings from the drum screens were macerated, pumped into a dewatering tank and allowed to settle for 45 minutes. The supernatant water was drawn off and the thickened screenings were then pumped into a tanker for delivery to the trial centrifuge. Screenings from the tanker were further macerated before delivery to the centrifuge. The results, presented in Table 3.8 were obtained using a Sharples P3000S centrifuge.

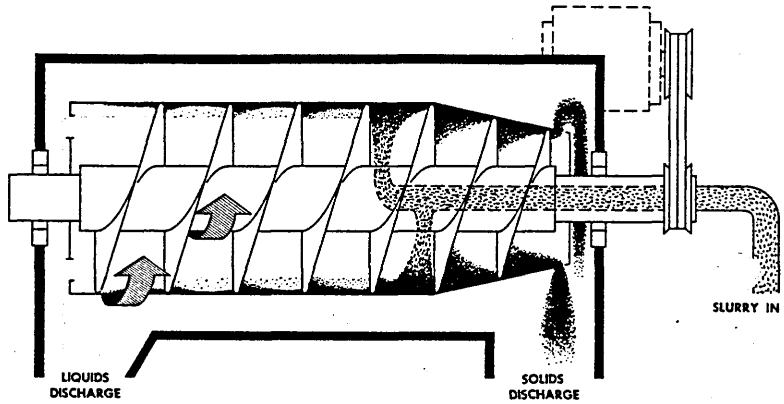


Fig. 3.15 A Decanter Centrifuge

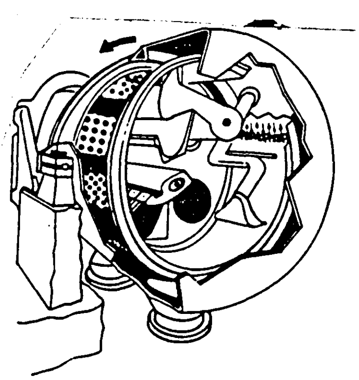


Fig. 3.16 A Basket Centrifuge

Table 3.8 Results of Tests Using a Decanter Centrifuge [138]

Test number	1	2[a]	3[a]	4	5[a]	6[a]	7	8[a]
Bowl speed (rpm)	3160	3160	3160	3160	3160	3160	3160	2600
Screen aperture size (mm)	4.4	4.4	4.4	4.4	4.0	4.0	4.0	4.0
Moisture content screenings (%)	99.03	98.88	98.21	98.25	96.46	96.27	96.14	96.12
Feed rate (m^3/h)	6.0	6.0	9.0	9.0	5.0	5.0	5.0	5.5
Overflow solids concentration (mg/litre)	1156	370	832	2150	3190	3295	4290	3300
Moisture content centrifuged screenings (%)	64.7	67.9	70.9	71.4	67.4	71.4	67.4	67.0
Solids recovery (%)	89.8	96.8	95.6	88.4	91.9	92.0	90.1	92.4

(a) With polyelectrolyte added

Recoveries of suspended solids in the range of 88 to 90% were achieved without the addition of polyelectrolyte; the moisture content of the centrifuged screenings ranged from 65 to 71%. The throughput obtained was 5 to $9m^3/h$. The suspended solids in the centrate were very fine and could readily be discharged with screened sewage. The success of these tests was, to a large extent, due to the fact that the screenings were macerated to a high degree prior to being fed into the machine.

Tests have been carried out using a perforated basket centrifuge for coarse unmacerated screenings. The screenings were batch fed and distributed about the chamber by hand. Polythene bags tended to blind the chamber wall and solids rapidly accumulated in these areas causing unbalance. The screenings contained a large proportion of rags which often tangled and were extremely difficult to remove from the chamber walls. It was considered that if the screenings had been macerated prior to dewatering, more satisfactory operations could have been achieved.

3.2.11 Disposal of Screenings

Methods of disposal of screenings are landfill, digestion (not practiced at present), composting, incineration and return to sewage flow following maceration. Whatever method is adopted it is important that disposal is carried out as soon as possible due to their foul odour, objectionable appearance and the associated health risk.

The increasing proportion of non-biodegradable matter in screenings means that when deciding between separate disposal or return to flow consideration should also be given to the method of sludge disposal and the possible effects of increased non-biodegradable matter in the sludge from the maceration of screenings.

3.2.13.1 The maceration of screenings and their return to the sewage flow, or the comminution of sewage solids within the sewage flow, followed by the subsequent processing of the resulting solids with the sewage sludge have been regarded for many years as a single, clean and hygenic method of screenings disposal. Although the disposal of screenings is eliminated,problems may occur in subsequent treatment processes due to the presence of the disintegrated solids. Problems commonly encountered are 'balling-up', scum formation in sludge digesters and non-biodegradable matter in sludge disposed of to land. In view of this it is considered that this method of disposal is most suitable for small sewage works where there is no mechanical treatment of the sludge and no danger from non-biodegradable matter.

3.2.13.2 Landfill or burial is simple and probably the most economic means of disposal for small and very small sewage works, although it is also the most labour intensive method. Problems may occur in the handling of screenings due to their objectionable nature. For medium and large works this method of disposal is usually unsuitable due to the shortage of manual labour and suitable land. It is important that the screenings are buried as soon as possible to reduce the risks of nuisance. Screenings may be bagged after some dewatering to reduce their offensiveness in subsequent disposal by tipping.

Screenings should be covered sufficiently to prevent odour, fly breeding and the attention of birds and rodents. If disposal is on site, trenches are usually excavated to a depth of 0.6 to 0.9m, the screenings placed therein and covered with about 0.45m of soil. Creosote and bleaching powder are often added to screenings before burial to reduce odour and discourage rodents.

It is important that if on site burial is adopted that sufficient land be allocated for this purpose at the time of design. For example a sewage works producing 1 m^3/d of screenings would require about 0.6 hectares for the burial of screenings. This allows re-use of the area every five yers over which period decomposition of the screenings should have taken place. If screenings are transported to a local landfill site, care should be taken to ensure that the transportation is hygienic and does not cause a nuisance to any local residents and that the tipped screenings are immediately covered by refuse.

3.2.13.3 Composting could be used as an alternative to burial of screenings at a small or very small works, although the increasing plastic and synthetic fibre content could make it less effective. Composting has been used successfully in other warmer countries and if longer periods are allowed for proper degradation there is a good change of success in this country.

3.2.13.4 There are three methods for the incineration of screenings:

Municipal refuse incinerator
Sludge incinerator
Screenings incinerator

(a) Municipal Refuse Incinerator

This is perhaps one of the simplest methods of disposal and is practised at a number of works. Due to the nature of screenings it is unlikely that any refuse disposal authority would accept screenings without some prior dewatering. Inoffensive transportation to the incinerator may be effected either in a closed container or by bagging the screenings. Pressed screenings could require breaking up before being fed to the incinerator to ensure complete incineration.

(b) Incineration with Sewage Sludge

A sludge incinerator could be used for the incineration of screenings providing care is taken over the charging of the screenings. Although it has not been tried in the U.K., up to the present time, it is a practice which has been adopted in the U.S.A. There is generally no need to dewater screenings before feeding into the incinerator unless either the screenings to sludge ratio is higher than normal or the sludge is only marginally autothermic. With certain types of sludge incineration it may be preferable to macerate the screenings before incineration.

If a multiple-hearth incinerator is used for sludge incineration, screenings should be fed in to the 3rd hearth from the top to optimise odour control. Charging can be by means of a conveyor and a flap gate, a pneumatic ejector or by manual charging.

(c) Screenings Incineration

There are two basic types of screenings incinerator presently available:

Vertical cylindrical incinerator with rabble arms
Rotary drum incinerator

1. Vertical Cylindrical Incinerator

This type of incinerator is basically a vertical cylindrical combustion chamber having a fabricated steel shell lined with refactory materials. The lid of the chamber is similar and may be made removable. The floor of the combustion chamber is formed from high grade steel castings supported on steelwork. The grate has slots to allow the ash to pass through while preventing large incombustable objects falling through. Hence it is necessary to remove such objects manually. The ash is removed daily by means of an ash can or it can be discharged down a chute into the sewage flow for subsequent settling out in the primary settlement tanks. Screenings on the grate are continuously agitated by rotating rabble arms, which break up agglomerates and assist in the drying and combustion of the solids. The combustion chamber temperature is maintained by natural gas, sludge gas or fuel oil remove. Exhaust gasses can be passed through an afterburner to ensure complete oxidation or noxious gases. Charging of the incinerator may be either manually (on a batch basis) with the screenings in plastic bags, or continuously by means of a conveyor. Sizes of incinerator range from 125 kg/h up to 500 kg/h pressed screenings.

2. Rotary Drum Incinerator

This type of incinerator consists basically of a refactory lined steel drum set at a slight angle to the horiziontal and which revolves at a low speed. Screenings are fed in at the top of the drum and are burnt as they progress down the drum. Residence time within the drum is depadent on the angle of inclination and speed of rotation of the drum. The inside face of the drum is stepped to stop material folling quickly through the drum. Supplementary heat is provided by a burner mounted either at the front or rear of the drum. Problems may be encountered with front mounting due to steam from the incineration of wet screenings putting out the flame. An afterburner is generally fitted to ensure complete combustion of any noxious gases. This type of incinerator usually has a continuous feed and is available in sizes handling up to 200 kg/h. The advantage of this type of incinerator is that there are no moving parts within the combustion chamber.

The fuel requirements of incinerators vary considerably but the figures presented in Table 3.9 may be sued as a guide.

The dewatering of screenings prior to incineration reduces fuel costs although little advantage is gained by reducing the water content below the point at which screenings become autothermic. Prior dewatering also results in the incinerator not having to be designed to handle large volumes of screenings at times of peak flows, as the screenings may be sotred after dewatering. Where screenings are fed directly to the incinerator without pressing, precautions are needed to prevent the incinerator from becoming overloaded at times of storm and from being charged with screenings of too high a moisture content. The first may be accomplished by directing the screenings into a storage skip and the second by the use of an inclined conveyor that allows drainage of the screenings before delivery to the incinerator.

The optimum temperature range for screenings incineration is 800 to 900°C.

Table 3.9 Fuel Requirements of Screenings Incinerators

Type of incinerator	Handles screenings of moisture content (%)	Feed rate (kg/h)	Fuel consumption
Vertical cylindrical	80	250	22.5 l/h[a]
Rotary drum	70-75[c]	159	57 m^3/h[b]
Rotary drum	85-90[c]	73[d]	396 m^3/d[b]

(a) fuel oil

(b) sludge gas

(c) estimated

(d) design rate

The lower temperature is the minimum temperature required to destroy noxious gases but to raise the temperature above 900°C makes the incinerator less economical. The reduction by weight achieved by the incineration of screenings is normally about 98%.

3.2.14 Transportation and Handling

Due to the offensive nature of screenings, screening installations require designing the minimise the handling of screenings. At present there are four basic methods employed for screenings transportation and handling

Screenings Troughs
Conveyors
Jubilee Wagon and Skips
Bagging

(a) Screenings Troughs

These are usually made in steel but sometimes concrete is used. Shallow semi-circular troughs are normally used where screenings are manually removed from the trough. The deeper V-shaped trough with a semi-circular insert is used where waterborne screenings are carried to a macerator. The sparge water velocity in this latter type needs to be at least 1 m/s. A rectangular trough with holes in its base is often used in conjunction with hand-raked screens.

(b) Conveyors

There are two basic types of conveyor, box or drag chain conveyors and belt conveyors. Box conveyors have an advantage over belt conveyors in that they are totally enclosed and may be installed at steeper angles; though the cost is about double. Belt conveyors, linked to the raking mechanism and automatically controlled, are most commonly used for the conveyor transportation of screenings. Normally, these are trough belt conveyors. The minimum length for adequate troughing is about 6m and the feed point to tail drum distance should be about twice the belt width. The maximum angle of inclination of this type is between 18 and 20^{o}. Detergents and oils cause rubber belts to deform. Neoprene belts do not suffer from this, and a belt with a 3mm top layer of neoprene should have a life of about 10 to 12 years. Endless belts are preferable with a scraper provided at the discharge end. A speed of 7.5m/min has been recommended for the belt travel rate. Problems do occur with the adhesion of wet screenings to the belt and resultant fouling of the conveyor mechanism.

(c) Jubilee Wagons and Skips

Jubilee wagons are four wheeled trucks which travel on rails and are still used for the transportation of screenings but they are gradually being replaced with skips as these allow greater flexibility. It is possible to arrange with certain types of screen (e.g. grab screen) for the screenings to be discharged directly into the wagon or skip. If screenings are transported off the works site, the skip needs to be fitted with a cover.

(d) Bagging

Bagging units are generally used in conjunction with screenings presses when the dewatered screenings are stored prior to disposal to make handling more inoffensive. They take a charge of 10 to 12 bags providing a total capacity of 0.9 or $0.6m^3$ of pressed screenings. The bags, made of polythene or polythene lined paper, are filled in turn with either a load-cell or level sensing unit being used to determine when a bag is full. The unit then automatically rotates to allow another bag to be filled. When all the bags are full, an audible warning is sounded. The bags may be filled either direct from the press or via a conveyor.

4. SCREENINGS

4.1 VOLUMES OF SCREENINGS

During the questionnaire survey screenings' volumes data were obtained from 27 sewage treatment works and are summarised in Table 3.2. All the Works which submitted data were contacted to find out if they kept detailed records of screenings volumes, and it was discovered that only eight kept these records, the remaining Works has supplied data based on observations and measurements at the time of the survey only. Seven of the eight Works supplied copies of sections of their records, whilst the eighth, Davyhulme Sewage Treatment Works, Manchester, stated that it did not keep seaprate records of screenings quantities, and so it was necessary to visit Manchester to abstract the required data from the workmen's bonus sheets. The data from the eight Works is given in the following tables:-

Table 4.1	Daily Sewage Flow and Volumes of Screenings; <u>Stoke Bardolph S.T.W., Nottingham</u>
Table 4.2	Monthly Quantities of Screenings and Average Flow; <u>Stoke Bardolph S.T.W. Nottingham</u>
Table 4.3	Daily Sewage Flow and Volumes of Screenings; <u>Davyhulme S.T.W., Manchester</u>
Table 4.4	Daily Sewage Flow, Weights of Screenings and Rainfall; <u>Atlincham S.T.W., Cheshire</u>
Table 4.5	Daily Sewage Flow, Weights of Screenings and Rainfall; <u>Ringfold S.T.W., Bolton</u>
Table 4.6	Daily Sewage Flow and Weights of Screenings; <u>Kew S.T.W., London</u>
Table 4.7	Monthly Sewage Flow and Volumes of Screenings; <u>Newbridge S.T.W., Lothian</u>
Table 4.8	Monthly Sewage Flow and Volumes of Screenings; <u>Pen Mill S.T.W., Yeovil</u>
Table 4.9	Weekly Average Sewage Flow and Volumes of Screenings; <u>Crossness S.T.W., London</u>

Unfortunately, there is no recognised standard format for the presentation of screenings data and this is reflected in the type and format of the data received. In four cases weights of screenings were given, in three actual volumes are quoted, whilst in two simply numbers of skips or tubs of screenings are quoted. This lack of uniformity in the presentation of information severely restricts the comparisons that can be made between works and the limited comparisons that can be made are summarised in Table 3.2.

Examination of the detailed data for daily quantities, affirms the conclusion reached from examination of the questionnaire replies, in that there appears to be no correlation between screenings' quantities and sewage flow, and also re-affirms the findings of Hendryx and Carrington[25] which were published in the USA in 1940. Tables 4.1, 4.3, 4.4 and 4.6 indicate the wide range of screenings' quantities that can be produced at a works from a particular sewage flow; they also incidate the large quantities of screenings which can be produced by storm flows. This latter phenomenon is particularly noticeable in Table 4.3 where the sewerage system draining to the works contains long lengths of large diameter sewers as shallow gradients where the solids settle out of the sewage at times of normal flow. But again this is no noticable pattern as not all storm flows produce large measures in the quantities of screenings. In Table 4.4, whilst there are large variations in the ratio of screenings' quantity to sewage flow, it is noticeable that there is not a particular increase in screenings' quantities at times of storm even after long periods of dry weather. It must therefore be assumed that in the case of Altrincham, the sewers generate self-cleaning velocities at times of normal flow and there is no build-up of solids within the sewerage system. At Manchester, Table 4.3, the skips are not normally emptied on a Sunday and the lack of any general increase in the number of skips emptied on a Monday, is an unexplained anomaly. The figures for Ringfold Sewage Treatment Works, Bolton, Table 4.5, whilst demonstrating the usual variation in the ratio between screenings' quantities and flow, are suspect, due to uniformity of the results with regard to daily quantities.

Tables 4.7, 4.8 and 4.9 use monthly and weekly figures and serve merely to emphasise the results obtained from the figures contained in the daily records.

Table 4.2, as well as giving monthly quantities and average flow, gives yearly totals of screenings and yearly average daily flows and would seem to indicate a correlation between quantity and flow on a yearly basis, but the reason for this is not clear. It is very unlikely that the original sources of screenings, population, institutions and industry, fluctuation to the extent indicated by the yearly variations in screenings' quantity. Whereas the flow clearly varies in accordance with the amount of rainfall, any direct connection between screenings quantity and rainfall is clearly unsupportable. The variation of quantities of screenings could be explained by the fact that increased flows reduce the retention time in the sewerage system, screenings therefore arrive at the sewage works fresher, in larger pieces and therefore greater quantities are removed.

It could be argued that there should be no direct relationship between total sewage flow to a works, which is influenced (to a greater or lesser extent, depending on the sewerage system) by rainfall, and total screenings (which must be independent of rainfall), but that there should be a close correlation between total screenings and flow to full treatment. Table 4.4, which records these latter two variables would seem to indicate that this is not so, for even in periods of prolonged dry weather, there is no correlation between flow for full treatment and screenings' quantities.

It is clear from the examination of Tables 4.1 to 4.9 inclusive, and Table 3.2, that there is no correlation between daily sewage flow and daily screenings' quantities, nor is there any fixed relationship between screenings' quantities, screen opening size and population. This appears to contradict the findings of Keefer[14] and Roebuck[21] shown in Figures 2.1 and 2.2, which indicate a direct relationship between screenings' quantities and variation in daily sewage flow. This could be explained by the fact that the concentration of screenings within the sewage flow remains fairly constant within a short time period, but can vary considerably on a daily basis, i.e. the factors causing those variations in the concentration of screenings have a long term rather than short term affect.

The factors affecting the quantities of screenings removed at a works are many, and it is the complex interaction of these factors which give rise to the problems in forecasting screenings' quantities. For not only do those factors vary from sewerage system to sewerage system, but also their effects vary from season to season and day to day. These factors are:

(a) Independent of the Sewerage System:

(i) Population

(ii) Standard of Living

(iii) Trade wastes, not only type but also extent of pre-treatment

(iv) Rainfall

(v) Seasons

(b) Within the Sewerage System:

(i) Screen opening size

(ii) Design of screen installation

(iii) Frequency of screen cleaning

(iv) Whether sewerage system is combined or separate

(v) Fluctuations in sewage flow

(vi) Length of sewerage system

(vii) Flow velocity in sewers

(viii) Retention time within sewerage system

(ix) Cleanliness of sewers

(x) Extent and type of pumping

(xi) Efficiency of storm overflows

(xii) Extent of screening of storm overflows

The above factors or variables are too many and their interaction too complex for screenings' quantities at a particular works even on a daily basis, to be predicted with any accuracy and makes the product of fixed standard quantities for a particular screen opening size impossible.

With regard to screenings' quantities at the times of storm; whilst the tables show large volumes, up to 7 x average in the case of Manchester, the tables also indicate the storm flows do not always mean a great increase in screenings' quantities, even after a prolonged dry spell.

4.2 DATA COLLECTION

Discussions with Water Authority personnel clearly indicated a resistance to the collection of data on screenings. The view held by those contacted was that in view of the wide variance in screenings' quantities at a particular works and the widely differing volumes of screenings for the same screen opening size at different works, no useful purpose could be gained from a programme of data collection involving methods of sampling and analysis, with a high degree of precision. Data collected from a particular works, it was felt, would be applicable only as a guideline figure for future design and then should be undertaken at the design stage. Also, it was considered that due to the objectionable nature of screenings, it would be difficult to get men to undertake a long term sampling and testing programme. The data obtained from particular works tends to support these views and therefore it was decided not to proceed with a programme of data collection. However, methods of sampling and analysis were evolved and these are given in Appendix 'A'.

Water Authority personnel and manufacturers were generally of the opinion that the data given in the Institute of Water Pollution Control's booklet 'Unit Processes - Preliminary Processes'[13] was sufficient for most practical purposes, with special investigations being carried out at a particular works should the type of equipment being installed so demand, and adequate provisions being made to deal with measured quantities from storm flows. Roebuck[21] has recently demonstrated the need to ascertain concentrations of screenings at a works when designing a fine screen and he gives details of a method of obtaining this figure.

The following may be considered typical of the characteristics of screenings, and used for most design purposes:

(i) Denisity

Varies between 600 and 1000 kg/m^3 [13]

(ii) Moisture Content

Varies between 75% and 90%[13]

(iii) Volatile Matter

Varies between 80% and 90%[13]

(iv) Calorific Value

The calorific on a dry basis varies between 17 000 and 21 000 kJ/kg[9,10]

(v) Volume

0.01 to 0.03 m^3/d per 1000 population[13]

The calorific value of any moisture content may be calculated using the following formula:-

$$K_m = K_o \left(1 - \frac{M_c}{100}\right)$$

Where K_m = calorific value of specified moisture content (kJ/kg)

K_o = calorific value of specified moisture content (kJ/kg)

M_c = specified moisture content (%)

Screenings usually become autothermic when the moisture content is reduced to 60 - 70%.

Day	January Flow	January Tubs	February Flow	February Tubs	March Flow	March Tubs	April Flow	April Tubs	May Flow	May Tubs	June Flow	June Tubs	July Flow	July Tubs	August Flow	August Tubs	September Flow	September Tubs	October Flow	October Tubs	November Flow	November Tubs	December Flow	December Tubs
1	109.89	5	145.79	5	115.45	5	132.31	6	193.84	8	104.48	5	157.09	5	104.89	5	129.54	6	138.15	5	133.94	12	310.71	12
2	138.92	5	141.75	5	120.52	5	171.76	8	192.60	9	191.52	8	129.55	6	90.13	15	123.68	8	239.50	10	149.10	7	190.41	5
3	135.33	6	163.99	6	152.24	8	154.11	7	123.10	7	131.23	5	128.15	6	88.94	5	125.01	6	136.38	5	139.13	6	149.37	5
4	111.59	5	160.01	5	144.85	5	158.11	6	112.60	6	133.24	5	127.26	6	110.91	6	126.54	5	102.87	5	132.88	5	139.66	6
5	111.60	5	153.39	6	165.50	8	148.33	9	142.97	5	130.53	5	99.88	5	129.16	6	122.27	6	119.35	5	207.43	9	137.33	6
6	148.31	7	159.86	6	177.35	7	119.29	8	144.52	6	132.67	6	96.56	4	108.38	6	96.63	5	145.30	5	115.14	6	109.80	5
7	146.46	6	151.10	6	157.67	8	157.16	6	256.85	8	109.21	5	138.20	7	110.40	5	92.30	5	128.50	7	123.72	6	108.82	5
8	137.96	5	124.11	5	149.20	7	153.55	5	169.76	5	126.50	5	157.73	11	110.95	5	133.30	7	125.75	6	96.10	5	130.44	6
9	141.82	7	123.55	6	271.65	10	149.81	5	154.34	6	141.11	6	142.41	12	94.58	5	120.34	6	156.05	6	106.41	5	126.77	6
10	136.63	6	175.69	6	231.65	8	153.45	6	125.67	5	123.56	8	136.03	6	92.16	4	177.33	13	126.60	7	143.66	6	129.30	7
11	112.53	5	185.24	8	256.30	7	158.82	6	120.20	5	146.37	5	124.24	5	125.31	5	166.12	12	94.85	5	123.08	6	129.90	5
12	138.98	12	151.17	5	223.96	5	114.44	4	173.95	8	172.58	6	126.42	5	124.99	5	144.45	6	95.75	5	123.22	6	126.60	6
13	148.95	5	209.68	8	226.93	7	124.29	5	158.88	9	139.94	7	94.90	5	117.00	5	125.05	6	126.30	6	122.15	7	97.40	5
14	159.36	6	166.34	6	186.98	6	190.88	8	200.12	7	102.17	5	125.67	6	188.52	8	99.05	7	125.65	6	120.37	6	99.48	5
15	156.01	7	129.63	5	149.85	5	172.00	7	154.78	5	100.01	5	129.53	6	134.57	6	128.40	6	174.49	6	193.39	10	118.81	6
16	143.26	5	122.71	5	141.80	5	176.22	5	155.20	6	145.71	10	125.45	6	92.56	5	123.75	5	131.34	6	104.22	5	126.81	5
17	145.74	6	151.32	6	173.03	6	214.63	8	135.68	6	148.98	6	145.03	8	92.08	5	182.40	8	120.24	6	129.70	5	122.62	6
18	110.11	5	158.00	6	157.04	6	210.34	7	117.52	5	123.85	5	218.35	15	122.84	6	128.88	8	92.83	5	170.92	6	121.77	5
19	157.61	5	142.67	5	155.53	5	147.51	6	152.36	5	136.18	5	132.21	5	138.86	6	129.42	7	128.80	5	149.12	7	119.10	6
20	185.59	10	145.88	6	161.58	5	147.83	4	144.01	6	129.88	6	101.23	5	130.08	5	101.53	5	121.38	6	137.35	5	94.90	5
21	194.98	9	135.70	5	221.41	7	176.94	5	140.53	7	104.29	6	133.93	6	123.37	6	94.17	6	122.58	7	125.16	6	97.95	5
22	205.70	7	117.20	6	159.72	10	162.34	6	136.55	6	99.07	5	129.27	5	122.20	7	125.95	7	120.84	6	96.25	5	114.85	7
23	166.03	5	127.49	6	148.20	6	157.58	5	129.16	5	135.12	6	146.03	6	86.98	6	167.60	7	122.15	5	99.90	5	122.42	5
24	184.90	6	142.68	7	170.39	5	156.97	6	101.42	5	124.78	6	122.87	6	93.51	6	123.65	6	118.90	9	133.19	8	98.68	6
25	153.92	7	140.10	6	161.37	6	166.24	9	94.07	4	132.84	6	112.55	6	107.55	10	163.80	9	93.50	5	140.65	8	70.94	5
26	213.05	6	140.55	6	157.15	7	117.74	5	92.73	5	133.06	5	92.62	5	117.85	5	159.62	6	95.30	5	134.88	6	76.13	6
27	206.93	7	142.75	5	155.17	7	114.16	5	113.28	5	121.75	5	97.23	5	123.28	6	128.33	7	125.15	7	152.34	8	87.22	5
28	231.04	8	134.63	6	136.18	5	147.96	6	120.71	6	98.51	4	115.47	6	124.13	5	99.60	5	124.50	5	129.62	6	81.76	6
29	198.26	5			112.22	5	149.94	6	117.67	6	100.83	8	133.81	6	123.78	6	132.85	7	123.62	7	96.73	5	112.30	5
30	184.33	6			110.89	4	152.04	7	117.74	6	151.03	6	115.35	6	141.72	7	169.15	11	126.38	5	94.14	6	126.90	6
31	197.18	6			102.11	5			102.68	5			104.27	5	96.82	7			122.90	6			159.56	6

Sewage Flow
1 tub conta
560 kg

Month	Year	1975	1976	1977	1978
Jan.	Screenings (t)	109	115	161	151
	Sewage Flow (ml/d)	158.5	144.0	194.5	187.0
Feb.	Screenings (t)	91	113	123	124
	Sewage Flow (ml/d)	147.9	150.7	281.4	183.4
Mar.	Screenings (t)	109	115	138	135
	Sewage Flow (ml/d)	166.3	150.9	187.7	173.2
April	Screenings (t)	104	113	137	174
	Sewage Flow (ml/d)	155.2	139.9	157.9	160.6
May	Screenings (t)	105	123	137	142
	Sewage Flow (ml/d)	141.8	140.2	165.4	167.1
June	Screenings (t)	98	113	132	142
	Sewage Flow (ml/d)	129.0	132.5	161.8	170.2
July	Screenings (t)	110	111	132	119
	Sewage Flow (ml/d)	127.1	126.9	142.9	154.7
Aug.	Screenings (t)	106	108	151	133
	Sewage Flow (ml/d)	115.1	118.4	156.4	155.9
Sept.	Screenings (t)	116	125	147	123
	Sewage Flow (ml/d)	131.4	141.4	148.4	149.7
Oct.	Screenings (t)	103	135	144	131
	Sewage Flow (ml/d)	126.6	165.3	151.5	144.4
Nov.	Screenings (t)	108	117	215	132
	Sewage Flow (ml/d)	127.7	150.6	171.4	148.2
Dec.	Screenings (t)	100	120	156	143
	Sewage Flow (ml/d)	123.8	159.1	170.2	208.5
Total Screenings (t)		1259	1408	1773	1649
Av. Daily Flow (ml/d)		137.5	143.3	174.4	166.9
Total Rainfall (mm)		522.4	457.1	698.3	655.0

Daily Sewage Flow & Volumes of Screenings - Davyhulme STW - Manchester

1975

Day	September		October		November		December		January		February	
	Sewage Flow (ml/d)	Sc'g (skip)	Sewage Flow (ml/d)	Sc'g (skip)	Sewage Flow (ml/d)	Sc'g (skip)	Sewage Flow (ml/d)	Sc'g (skip)	Sewage Flow (ml/d)	Sc'g (skip)	Sewage Flow (ml/d)	Sc'g (skip
1			429.60	3	–	6	1148.32	6	897.83	–	328.22	–
2			702.36	4	541.43	–	726.91	2	921.02	2	350.04	3
3			417.78	2	348.22	4	471.42	2	655.53	–	348.68	3
4			458.24	–	334.59	3	386.41	2	859.19	–	341.86	3
5			359.59	2	365.50	3	349.13	2	730.09	3	388.22	3
6			344.13	2	349.13	3	355.49	3	653.53	2	591.44	6
7	213.21	2	324.13	2	320.95	4	327.31	–	478.24	2	370.05	5
8	333.68	5	320.95	2	297.31	3	353.22	4	494.60	3	319.58	–
9	343.68	2	388.68	4	291.85	–	332.31	2	798.73	8	417.32	3
10	430.96	2	332.77	2	325.95	3	348.22	3	615.53	2	414.60	4
11	328.22	2	308.22	–	338.68	2	343.22	2	432.78	–	305.04	3
12	415.50	–	295.49	3	288.67	3	337.31	3	461.42	3	978.75	6
13	320.04	–	303.67	3	316.86	2	284.58	2	420.96	3	426.41	2
14	261.40	3	305.95	3	328.68	6	282.76	–	389.14	3	386.41	5
15	293.04	3	–	–	836.01	–	323.22	3	376.86	4	319.13	–
16	303.67	3	319.13	3	355.50	–	319.58	2	377.32	3	368.68	3
17	432.32	3	285.94	3	337.31	3	321.86	2	307.31	2	375.50	3
18	335.04	3	272.76	3	347.31	2	333.22	2	354.13	–	354.59	3
19	405.96	3	272.76	2	527.79	6	322.77	2	515.52	3	338.68	3
20	211.39	–	301.85	2	363.23	2	267.30	2	570.07	5	340.95	3
21	247.76	3	309.13	2	329.13	2	285.94	–	477.78	3	317.31	3
22	298.22	3	312.31	2	287.31	–	306.40	4	529.15	3	372.77	9
23	336.40	2	353.22	2	304.58	–	391.41	3	537.79	3	485.51	6
24	432.78	11	310.95	2	351.86	6	469.60	6	376.41	3	372.77	5
25	765.09	3	255.94	2	614.16	12	286.85	–	339.59	–	347.31	3
26	469.42	2	265.03	–	401.87	4	227.75	–	457.78	3	352.32	2
27	480.97	–	300.49	2	496.42	3	265.49	–	358.68	5	327.31	3
28	321.86	3	299.13	3	377.32	1	255.04	–	332.77	3	311.40	2
29	429.14	3	298.67	3	310.04	3	285.94	5	330.95	3	340.04	–
30	513.70	5	307.31	3	326.86	–	433.69	3	324.13	3	–	–
31	–	–	681.90	4	–	–	837.83	8	330.95	3	–	–

1 skip = $2m^3$ (approximately)

TABLE 4.3 (Cont'd)

1976

	March		April		May		June		July	
	Sewage Flow (ml/d)	Sc'g (skip)	Sewage Flow (ml/d)	Sc'g (skip)	Sewage Flow (ml/d)	Sc'g (skip)	Sewage Flow (ml/d)	Sc'd (skip)	Sewage Flow (ml/d)	Sc'g (skip)
1	345.04	5	460.06	3	446.02	19	368.23	4	311.86	3
2	334.59	5	388.68	4	491.48	-	360.04	3	259.94	3
3	338.68	3	320.95	2	618.39	3	320.04	4	350.04	3
4	342.31	3	300.04	-	369.09	4	303.22	3	289.58	5
5	334.59	3	349.59	4	527.47	4	277.31	2	318.22	9
6	287.31	-	377.77	2	384.27	3	270.49	-	301.40	3
7	285.94	-	422.78	4	645.67	4	314.13	3	306.86	3
8	323.22	3	334.13	3	456.56	3	317.77	3	307.76	3
9	298.22	2	340.50	2	277.44	-	310.49	3	365.95	3
10	310.49	2	320.49	3	336.47	3	300.95	3	203.66	3
11	419.14	3	261.40	-	354.65	3	302.31	3	299.13	-
12	350.95	2	339.13	6	426.93	4	242.30	3	472.33	21
13	327.77	3	536.88	-	349.65	3	261.85	-	334.13	4
14	245.03	-	460.51	8	339.65	3	305.04	4	311.86	3
15	335.95	4	368.23	15	354.20	3	309.58	3	473.24	13
16	355.95	4	291.29	-	317.37	9	375.95	3	299.13	3
17	377.77	4	248.67	11	368.36	3	395.96	19	280.49	3
18	330.04	2	279.58	-	361.08	4	377.32	3	314.12	-
19	338.22	3	297.31	11	565.20	3	416.41	4	384.59	16
20	267.76	2	333.22	3	447.46	5	250.94	-	314.13	3
21	910.11	7	335.95	4	340.63	3	315.95	5	307.31	3
22	509.15	3	339.13	4	339.72	3	302.76	3	297.31	3
23	378.23	3	306.40	3	277.89	-	310.04	3	316.40	3
24	412.32	3	318.67	3	430.96	3	312.76	3	233.66	3
25	905.11	6	288.67	-	673.72	12	321.86	3	-	-
26	470.06	5	324.64	3	356.86	6	257.30	3	-	-
27	345.95	3	321.91	3	340.95	6	264.58	-	-	-
28	360.95	-	312.37	3	446.87	3	307.31	4	-	-
29	424.60	3	314.64	3	315.95	4	323.68	3	-	-
30	395.96	-	336.46	3	440.96	-	314.58	3	-	-
31	379.14	2	-	-	276.40	6	-	-	-	-

Daily Sewage Flow, Weights of Screenings and Rainfall
- Altrincham Sewage Treatment Works, Cheshire (1975 - 76)

	November			December			January		
	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)
1	2.0	11.2		5.6	23.3		17.8	20.4	
2	2.5	13.0	1.0	26.4	19.1	1.0	13.2	22.3	
3	10.4	11.1		Nil	16.4		3.3	17.1	1.0
4	Nil	9.3	1.0	Nil	14.4	0.5	10.2	23.0	
5	0.76	10.5		Nil	13.5		3.6	21.1	
6	2.5	9.9		Nil	13.1		5.1	19.5	
7	Nil	9.1		Nil	12.7	1.0	Nil	18.4	1.0
8	Nil	9.5	1.0	Nil	12.2		6.9	16.9	
9	Nil	8.9		Nil	11.7		5.6	21.1	
10	Nil	9.6		Nil	12.1	1.0	1.5	19.0	1.0
11	2.0	8.9	1.0	1.3	12.2		Nil	16.8	
12	Nil	8.8		Nil	11.8		Nil	15.5	
13	Nil	9.0		0.5	11.2	1.0	Nil	13.8	1.0
14	Nil	9.4	1.0	Nil	11.3		Nil	13.8	
15	3.3	19.1		Nil	11.4		Nil	13.0	
16	14.7	11.9		Nil	11.2		Nil	12.5	
17	0.47	11.9	1.0	Nil	11.2	1.0	Nil	12.1	1.0
18	Nil	10.3		Nil	11.3		1.0	12.8	
19	4.8	12.4		0.5	11.1		3.3	14.2	1.0
20	Nil	11.5		Nil	10.8	1.0	1.3	16.6	
21	Nil	10.4		Nil	11.1		1.5	15.9	1.0
22	Nil	10.0	1.0	Nil	-	1.0	1.5	15.4	
23	Nil	11.7		3.3	-		Nil	13.0	
24	2.3	11.2		2.3	-		Nil	11.8	1.0
25	1.3	16.5	1.0	Nil	10.5	1.0	Nil	14.2	
26	5.3	13.6		Nil	9.4		Nil	12.2	
27	1.8	13.3	0.5	Nil	9.5		Nil	11.3	
28	1.0	11.4		0.76	10.1	1.0	Nil	10.9	1.0
29	Nil	10.7	1.0	Nil	10.1		Nil	12.0	
30	Nil	11.5		9.4	9.1	1.0	Nil	10.1	
31				14.7	20.9		Nil	10.1	

Day	February			March			April		
	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)	Rain-Fall (mm)	Flow (ml/D)	Sc'g (t)	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)
1	Nil	10.3	1.0	Nil	6.9		4.1	14.6	
2	Nil	10.6		Nil	10.7	1.0	0.8	14.4	1.0
3	Nil	10.7	1.0	Nil	10.8		1.5	14.2	
4	Nil	10.8		Nil	10.4		Nil	11.4	
5	13.2	13.2		Nil	10.3		1.0	12.8	1.0
6	7.1	18.9		Nil	10.4	1.0	2.8	14.0	
7	10.2	14.0	1.0	Nil	10.1		Nil	14.1	1.0
8	Nil	12.6		Nil	13.4		Nil	11.3	
9	Nil	13.1		0.8	7.5	1.0	Nil	14.3	1.0
10	3.8	13.7	1.0	Nil	10.2		Nil	11.2	
11	2.8	13.1		3.6	12.6	1.0	1.0	14.2	
12	8.1	17.6		Nil	10.9		Nil	12.6	
13	Nil	15.5	1.0	Nil	10.2	1.0	8.9	18.4	1.0
14	Nil	14.3		0.5	9.9		0.8	14.1	
15	Nil	13.3		1.8	11.8		Nil	13.5	
16	Nil	11.4	1.0	4.1	12.9	1.0	Nil	11.4	1.0
17	Nil	13.5		Nil	11.2		Nil	12.0	
18	Nil	12.0		Nil	10.7		Nil	11.1	
19	Nil	11.4	1.0	Nil	10.0	1.0	Nil	11.4	1.0
20	Nil	11.6		7.4	11.7		Nil	11.2	
21	Nil	11.4		23.1	22.8		Nil	11.0	
22	4.1	14.4		Nil	16.5	1.0	Nil	11.0	1.0
23	Nil	14.7	1.0	Nil	13.1		Nil	10.4	
24	Nil	12.8		10.7	20.7	1.0	Nil	10.6	
25	Nil	12.5		5.6	17.0		Nil	10.1	
26	Nil	11.6		Nil	17.0		Nil	11.0	1.0
27	Nil	11.2		Nil	14.0	1.0	Nil	8.9	
28	Nil	11.7	1.0	2.0	15.2		Nil	9.9	
29	Nil	11.7		Nil	15.7		Nil	8.6	1.0
30				Nil	13.5	1.0	Nil	8.6	
31				Nil	14.6				

Daily Sewage Flow, Weights of Screenings and Rainfall
- Ringfold Sewage Treatment Works - Bolton (1976)

Day	January			February			March			April		
	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)
1	26.8	330.9	-	Nil	*	-	Nil	82.7	3.0	3.4	110.9	3.0
2	15.0	376.4	3.0	Trace	*	3.0	Nil	80.0	3.0	2.4	99.6	3.0
3		240.9	3.0	0.4	*	3.0	Nil	83.6	3.0	0.8	94.5	-
4	21.4	360.5	-	Nil	*	3.0	Nil	78.2	3.0	Nil	80.5	-
5	4.4	291.8	3.0	4.2	*	3.0	Nil	78.2	3.0	0.6	85.5	3.0
6	5.6	285.9	3.0	8.0	160.9	3.0	Nil	74.1	3.0	3.0	105.5	3.0
7	Nil	*	3.0	Trace	85.5	3.0	Nil	66.4	-	Nil	95.9	3.0
8	8.1	270.9	-	Nil	83.2	-	Nil	74.2	3.0	Nil	90.0	1.5
9	11.0	283.2	3.0	4.1	119.1	3.0	1.0	76.8	-	Nil	90.5	3.0
10	Trace	*	-	3.8	103.6	3.0	0.2	76.8	3.0	Nil	73.6	3.0
11	2.2	*	-	4.6	118.6	3.0	5.0	113.2	-	1.2	80.5	-
12	2.5	*	1.5	12.8	325.5	1.5	Nil	76.8	3.0	Nil	88.2	3.0
13	Trace	*	1.5	Nil	130.9	1.5	Nil	70.9	1.5	13.0	258.7	3.0
14	0.2	*	1.5	Nil	95.5	1.5	Trace	67.3	-	0.9	230.0	3.0
15	Trace	*	1.5	1.8	98.2	-	1.6	90.0	-	Nil	101.8	3.0
16	Nil	*	1.5	Nil	95.5	3.0	5.3	123.6	3.0	Nil	76.4	-
17	0.5	*	1.5	Trace	90.9	1.5	0.2	89.5	3.0	Nil	73.2	3.0
18	2.4	*	-	0.4	116.8	1.5	Nil	79.5	-	Nil	65.9	-
19	11.9	229.6	3.0	Nil	86.8	3.0	Nil	-	-	Nil	90.0	-
20	3.4	252.8	3.0	Nil	90.9	3.0	Nil	-	-	Nil	68.2	3.0
21	4.0	247.8	1.5	2.3	90.9	3.0	42.0	620.	3.0	Nil	72.3	3.0
22	5.6	266.8	3.0	1.4	87.7	-	Nil	157.7	3.0	Nil	69.6	3.0
23	1.6	231.8	-	4.5	116.4	3.0	Nil	111.8	3.0	Nil	69.6	3.0
24	Nil	*	1.5	Nil	95.5	3.0	14.6	237.3	3.0	Nil	64.1	3.0
25	Nil	*	-	Nil	90.9	3.0	12.6	354.6	3.0	Nil	59.6	-
26	4.5	210.0	3.0	Nil	100.0	3.0	0.4	235.9	3.0	Nil	77.4	6.0
27	Nil	*	3.0	Nil	90.0	1.5	Trace	115.0	-	Nil	75.5	3.0
28	Nil	*	3.0	Nil	73.2	3.0	Nil	97.7	-	Nil	79.1	3.0
29	Nil	*	3.0	2.9	95.0	-	Trace	100.9	3.0	Nil	75.9	3.0
30	Nil	*	-	-	-	-	Trace	91.8	3.0	Nil	79.1	3.0
31	Trace	*	3.0	-	-	-	2.0	95.9	3.0	-	-	-

* Record not working

Day	May			June			July		
	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)	Rain-Fall (mm)	Flow (ml/d)	Sc'g (t)
1	4.4	85.0	6.0	0.9	125.1	1.5	Nil	52.7	1.5
2	20.8	256.8	-	0.2	85.5	1.5	Nil	56.8	1.5
3	1.8	243.2	3.0	0.3	80.5	1.5	1.0	54.1	1.5
4	4.2	173.2	3.0	Nil	82.3	1.5	0.5	52.3	-
5	1.0	179.1	3.0	Nil	67.3	1.5	Nil	47.7	1.5
6	5.6	170.9	3.0	Nil	66.8	-	Nil	51.8	3.0
7	1.4	190.5	3.0	Nil	80.9	3.0	Nil	50.9	-
8	0.2	92.5	3.0	Nil	81.4	3.0	Nil	50.9	-
9	Nil	92.5	-	Nil	65.9	3.0	1.0	63.2	-
10	Nil	85.9	-	Nil	73.2	6.0	Nil	50.5	4.5
11	2.8	151.4	1.5	Nil	-	3.0	Nil	47.7	-
12	2.6	209.6	6.0	Nil	136.8	3.0	5.3	90.5	3.0
13	Nil	151.8	3.0	Nil	62.3	-	2.0	63.2	3.0
14	1.3	97.7	1.5	Nil	68.6	3.0	2.8	57.3	-
15	1.6	105.9	-	0.2	71.4	3.0	7.1	108.6	3.0
16	Nil	83.2	-	8.6	108.6	3.0	Nil	70.5	-
17	5.0	178.2	3.0	0.6	96.8	6.0	Nil	47.7	-
18	2.3	118.2	3.0	1.3	-	-	4.2	64.5	-
19	15.2	255.9	3.0	1.1	148.6	3.0	3.1	91.4	3.0
20	2.3	220.5	-	Nil	67.3	-	Nil	66.4	3.0
21	0.8	94.1	3.0	Nil	60.9	3.0	Nil	62.7	-
22	Nil	90.9	3.0	Nil	71.4	3.0	Nil	57.7	-
23	Nil	76.8	-	Nil	75.0	3.0	Nil	65.9	3.0
24	17.0	113.2	7.0	Nil	70.5	3.0	Nil	50.5	3.0
25	0.6	236.8	3.0	Nil	71.8	3.0	Nil	51.4	-
26	Nil	92.3	3.0	Nil	50.9	3.0	Nil	63.2	3.0
27	Nil	85.0	3.0	Nil	67.3	-	Nil	63.6	3.0
28	4.0	137.7	3.0	Nil	51.8	3.0	Nil	65.0	3.0
29	1.3	123.6	3.0	Nil	55.0	3.0	0.8	74.5	3.0
30	5.3	128.7	-	Nil	56.4	3.0	0.2	70.9	3.0
31	2.8	143.2	-	-	-	-	Nil	50.0	3.0

TABLE 4.6

Daily Sewage Flow and Weights of Screenings - Kew Sewage Treatment Works - London (1975)

Date	Sewage Flow (ml/d)	Weight of Screenings (tonne)	Date	Sewage Flow (ml/d)	Weight of Screenings (tonne)
Sept. 1	32.98	0.381	Oct. 6	43.84	0.711
" 2	37.48	0.419	" 7	38.78	0.711
" 3	34.82	0.521	" 8	43.16	0.508
" 4	38.57	0.762	" 9	36.77	0.508
" 5,6 & 7	114.19	1.461	Oct. 10,11 & 12	118.36	1.486
" 8	37.10	0.724	" 13	42.70	0.813
" 9	39.30	0.610	" 14	37.64	0.610
" 10	36.35	0.813	" 15	38.46	0.711
" 11	39.41	0.711	" 16	36.23	0.635
" 12,13 & 14	127.49	0.978			
" 15	38.55	0.406	Nov. 14,15 & 16	119.77	1.854
" 16	40.81	0.533	" 17	37.05	0.813
" 17	38.42	0.635	" 18	38.25	0.234
" 18	38.28	0.597	" 19	39.88	0.622
" 19,20 & 21	115.26	1.067	" 20	39.22	0.330
" 22	37.45	0.457	" 21,22 & 23	113.66	1.334
" 23	37.78	0.711	" 24	37.06	0.613
" 24	36.51	0.610	" 25	39.85	0.457
" 25	44.91	0.508	" 26	37.09	0.508
" 26,27 & 28	124.48	1.118	" 27	38.24	0.813
" 29	40.84	0.711	" 28,29 & 30	123.93	1.118
" 30	39.29	0.508	Dec. 1	45.78	0.508
Oct. 1	41.57	0.610	" 2	42.64	0.356
" 2	39.77	0.711	" 3	40.24	0.613
" 3,4 & 5	117.58	1.194	" 4	38.94	0.457

Date	Total Monthly Sewage Flow (ml)	Maximum Daily Sewage Flow (ml/d)	Monthly Volume of Screenings (m^3)
July 71	229.8	13.5	3.4
August 71	335.9	26.6	3.8
September 71	214.3	9.6	2.7
October 71	256.7	18.0	4.6
November 71	281.9	15.2	1.1
December 71	275.2	12.8	1.1
January 72	269.0	13.8	3.1
February 72	293.6	15.6	3.4
March 72	275.6	13.0	5.4
April 72	332.1	18.6	2.3
May 72	250.3	11.9	2.3
June 72	249.9	10.7	3.8
July 72	187.7	10.7	1.1
August 72	190.2	7.8	2.3
September 72	235.7	9.5	2.7
October 72	246.2	12.1	1.5
November 72	260.0	14.9	2.3
December 72	322.3	23.0	6.1
January 73	304.6	14.9	2.3
February 73	285.3	17.0	2.3
March 73	268.8	10.7	4.6
April 73	282.0	12.4	2.3
May 73	309.4	20.2	1.5
June 73	245.6	12.6	1.1
July 73	272.2	15.1	1.1
August 73	251.0	13.0	1.1
September 73	229.1	11.9	1.1
October 73	269.7	16.5	2.3
November 73	270.1	11.8	3.8
December 73	359.3	26.8	2.3
January 74	376.0	17.4	3.8
February 74	329.5	20.7	3.8
March 74	304.4	13.0	3.8
April 74	255.9	12.5	-
May 74	270.3	12.9	1.5
June 74	260.8	15.2	3.8
July 74	262.0	13.3	2.3
August 74	290.4	18.8	3.4
September 74	312.3	18.4	5.4
October 74	276.8	12.5	3.8
November 74	418.6	22.8	-
December 74	522.1	31.2	-
January 75	537.7	31.1	1.9
February 75	335.1	16.0	-
March 75	281.2	11.4	3.4
April 75	278.6	14.6	-
May 75	288.2	15.0	2.3
June 75	246.1	11.2	2.3
July 75	242.8	14.2	2.3
August 75	252.7	14.8	2.3
September 75	355.7	24.8	4.6
October 75	311.2	18.4	3.1

Cont .....

TABLE 4.7 (cont'd)

Date	Total Monthly Sewage Flow ml	Maximum Daily Sewage Flow ml/d	Monthly Volume of Screenings m^3
November 75	259.3	12.9	2.3
December 75	273.1	16.6	2.3
January 76	382.4	24.5	4.6
February 76	291.2	14.5	2.3
March 76	332.9	21.5	2.7
April 76	377.8	36.7	2.7
May 76	297.4	16.3	5.4
June 76	287.5	14.6	5.4
July 76	251.9	14.4	2.7
August 76	252.8	13.4	-

TABLE 4.8

Monthly Sewage Flow and Volumes of Screenings; Pen Mill Sewage Treatment Works - Yeovil (1973)

Date	Total Flow (m^3)	Volume of Screenings (m^3)
January	474.800	33
February	380.800	30
March	383 000	40
April	475 000	35
May	516 800	27
June	449 000	28
July	491 900	21
August	420 800	22
September	381 400	20
October	405 500	22
November	375 800	21
December	446 300	21

Crossness Sewage Treatment Works - London (1975 - '76)

Week Ending 0900 hours Monday	Average Flow (1/s)	Volume of Screenings (m^3)
18.8.75	5861	54
25.8.75	5546	54
1.9.75	5268	54
8.9.75	5462	54
15.9.75	7229	54
22.9.75	6724	54
29.9.75	8182	54
6.10.75	7535	54
13.10.75	6183	54
20.10.75	6309	54
27.10.75	5778	54
3.11.75	5919	54
10.11.75	6051	54
17.11.75	6677	65
24.11.75	6756	72
1.12.75	7577	75
8.12.75	8313	57
15.12.75	6340	57
22.12.75	6230	60
29.12.75	6398	54
5.1.76	6425	45
12.1.76	6550	57
19.1.76	6093	63
26.1.76	6135	54
2.2.76	6056	57
9.2.76	6056	63
16.2.76	7488	63
23.2.76	6067	45
2.3.76	6151	42
8.3.76	5998	48
15.3.76	6025	54
22.3.76	6156	54
29.3.76	6056	54
5.4.76	6046	87
12.4.76	5925	48
19.4.76	6382	36
26.4.76	5704	72
3.5.76	5841	90
10.5.76	6151	72
17.5.76	5846	48
24.5.76	6440	90
31.5.76	5735	60
7.6.76	5766	60
14.6.76	5809	62
21.6.76	6435	54
28.6.76	6014	90
5.7.76	5925	60
12.7.76	5714	48
19.7.76	6682	60
26.7.76	5735	60
2.8.76	5141	57

5. DISCUSSION

5.1 GENERAL

This research project investigates the methods and problems associated with the separation, treatment and disposal of screenings at sewage treatment works, and although this forms an important part of the treatment process it is still generally only one of a series of processes to which the sewage is subjected prior to discharge to the receiving waters. Whereas, at storm water overflow and sea outfalls screenings can be the only process and therefore it is relatively more important. Aspects of the methods of screening at these locations and some of the associated problems are discussed in the following sub-sections.

5.2 STORM OVERFLOWS

The need for screening storm overflows to prevent the release of solids to surface watercourses is being increasingly appreciated in the U.K., and overseas. For instance, the United States Government had funded several projects during the past ten years on this subject. The Environment Protection Agency report by Lager and Smith[42] is one of the main reports to result from these projects. Talley[140] reviewed storm water sewage control in the U.K., and the U.S.A., and outlined some locations where some form of control was urgently needed.

In this country storm overflow control was considered in depth in the 'Final Report of the Technical Committee on Storm Overflows and the Disposal of Storm Sewage'[141] and mentioned briefly in the 'Report of the Working Party on Sewage Disposal'[142]. Discussions with Water Authority personnel have confirmed that control of storm overflows is considered desirable. At present automatic screens are only being requested on major storm overflow although factors taken into account are the siting of the overflow, the nature of the receiving water, and the recreational or industrial use of the receiving water. The screen opening most generally used is 20mm.

Ackers *et al*[145] reporting experiments carried out at Luton sewage works, considered that the majority of biochemical pollution in storm overflows results from material which will pass through a 6mm opening. No other research appears to have been carried out recently on the screening of storm overflows in this country. Detailed below are the types of screens installed if screening of storm sewage is carried out.

5.2.1 The 'Wilks' Screen

The 'Wilks' self cleaning storm screen has been in use for many years and is still being installed for small applications in this country. The screen is set parallel to the direction of flow, and consists of vertical bars set at an angle of 30^{o} to the flow. Therefore the sewage has practically to reverse its direction to pass through the screen. This screen, as with all storm screens, is positioned above the dry weather flow level and hence is normally out of use but in times of storm flow rises to the level of the screen. The flowing sewage cleans the front of the bars and tends to carry forward solids which may adhere to the bars thereby preventing blockage of the screen. In the U.K., opinions on this type of screen have been found to be varied. Screens installed in the Bedlington area are reported to be working satisfactorily, whereas at Ackworth the Wilks screens requires cleaning after every storm because of blockages from rags and paper.

The limitations of this type of screen are that it is not suited to systems which overflow frequently and that as this type is not completely self-cleaning a cleaning programme as well as a maintenance programme is required.

5.2.2 Curved Bar Screens

The curved bar screen for single or double sided weirs as shown in Figure 5.1 has an electrically driven rotating arm attached to two rakes. These remove the screeings from the screen and deposit them in the foul sewage flow. The most common bar opening for these screens in the U.K., is 19mm but 12 and 25mm openings may also be obtained as standard sizes. The rakes are activated by electrodes at

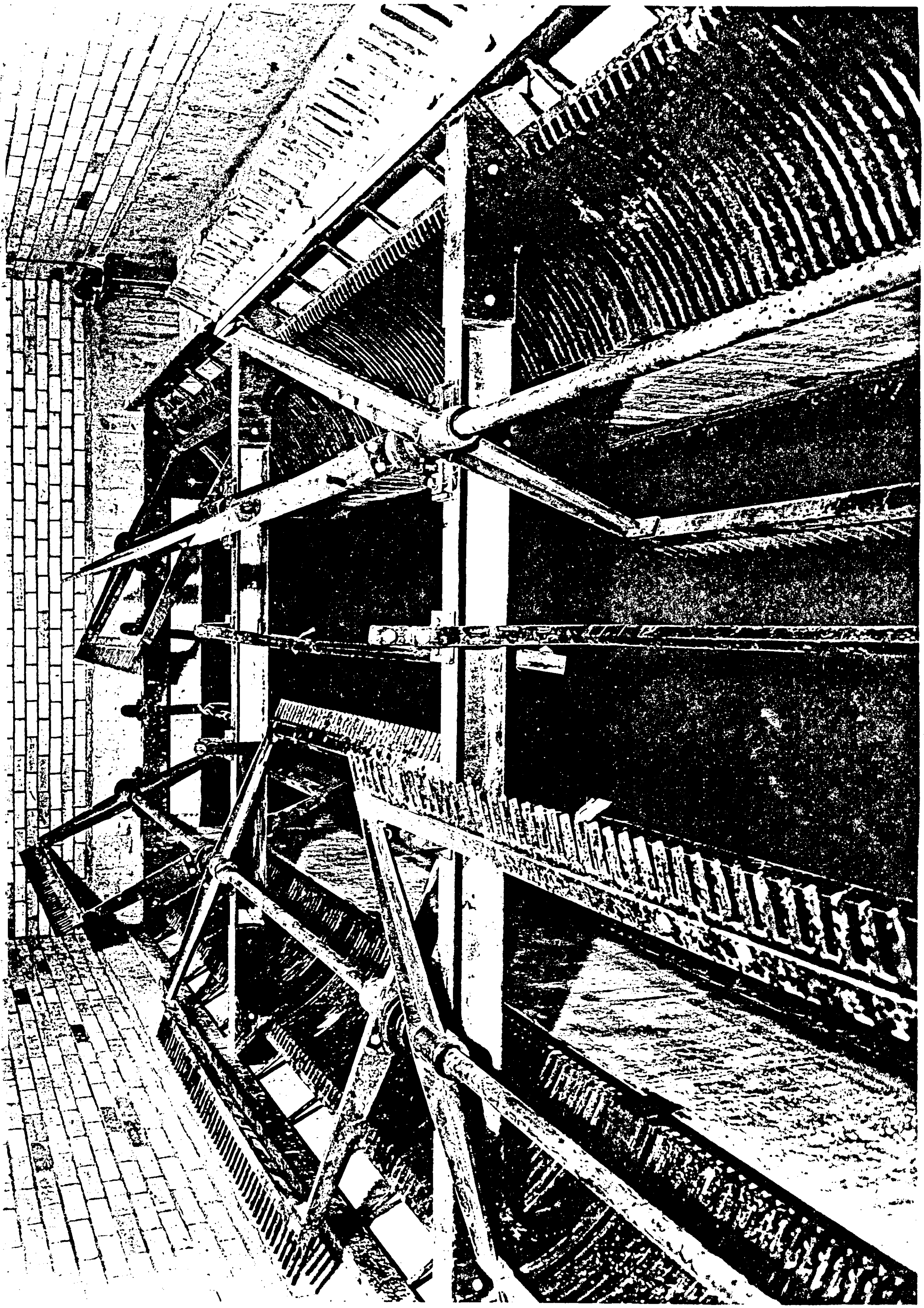


Fig. 5.1 Curved Bar Screen for Double Sided Weir

weir level but an overriding time clock ensures that the rakes operate for a short time every day during dry periods. These screens can handle a maximum sewage head of 900mm and it has been recommended that the velocity through the screen be limited to a maximum of 1.5m/s. Many screens of this type have been installed during the past few years and they generally appear to be operating satisfactorily.

The curved bar screen may also be used for stilling bay overflows where the screen is situated directly over a channel. The screenings are raked back into the foul sewage flow in a manner similar to the side weir screens. If necessary a chute is attached to the edge of the screen to direct the screenings into the centre of the sewage flow otherwise screenings collect on the benching of the chamber.

5.2.3 Vertically Raked Bar Screens

The vertically raked bar screens may be used at side weirs in deep channels. The screenings are raked downwards into the foul sewer on the downware travel of the rake mechanism whilst on the upward travel the rake swings clear of the screen bars and is washed by the foul sewage flow. The rake drive and controls are all set above ground level. Maximum width of this type of screen is three metres, but for wide overflow weirs two rake assemblies may be used; This type of screen is installed in this country although it is not as common as the curved bar screen.

5.2.4 Fine Screens

This is a practice mainly carried out in the U.S.A. The types of screen which have been used are the Sweco Wastewater Concentrator, Bauer Hydrasieve and various rotary fine screens. Lager and Smith(42) reported tests on four types of screen. It is pertinent to note that microstrainers can serve a dual purpose in that they can also be used for tertiary treatment of sewage during dry weather. Vickerys(149) claimed removals of 98% floatable solids, 35% suspended solids and 35% BOD with the hydrasieve in tests on storm overflows.

From similar tests Lager and Smith[42] concluded that efficiency of straining increases as the size of screen opening decreases. The volume of screenings produced by the coarse screening of storm overflows may be large. The use of fine screens therefore produces even larger quantities; Lager and Smith[42] considered that the volume of screenings from the fine screening of storm overflows could be several orders of magnitude greater than the volume normally handled by a sewage works practising coarse screening of dry weather flow only. Hence one of the main problems in designing screenings separation, treatment and disposal installations for storm overflows is the lack of available data, both from the U.K., and overseas.

5.2.5 Miscellaneous

Storm overflow screens require regular maintenance otherwise they may become blocked resulting in an increased loading on the treatment works or local flooding.

The installation of any of the screens mentioned above results in an increased volume of screenings being received at the treatment works during a storm. The screens and screening treatment process at the works should therefore be designed accordingly.

5.3 SEA OUTFALLS

One of the main objections raised to the discharge of sewage to sea is on aesthetic grounds. Where crude sewage is discharged around the low water mark, the presence of gross sewage solids is offensive and clearly indicates the need for remedial action. Faecal solids are particularly resistant to disintegration in seawater. However, aesthetic standards are widely applied or recommended in various countries for coastal waters used for recreational purposes[145]. Aesthetically, there are two main conditions to be met. Firstly, that solid matter visually identifiable as originating from sewage should not be able to reach areas used for bathing or water sports and secondly, that the points of discharge should be sited to render any sewage slick inoffensive to people on shore or in offshore recreational areas. The first condition can normally be achieved by screening or maceration of the sewage before discharge, although maceration may increase the problems of slick formation and thereby make compliance with the second condition more difficult.

5.3.1 Screens

Coarse bar screens have been used until fairly recently to screen sewage at sea outfalls but modern practice tends towards the use of rotary fine drum or cup screens with mesh perforations ranging from 5 to 10mm. To date preference has been given to the smaller size of perforation due to the increased solids removal.

5.3.2 Comminutors

The advantage of comminutors over screens is that there is no problem of disposal of screenings. A number of modern schemes have been constructed incorporating comminutors but the evidence of any advantage resulting from comminution is inconclusive. Some authorities on sewage disposal consider that screenings should be removed and not returned to the flow whereas others consider that with modern long sea outfalls and multiple diffusers comminution is an adequate method of treatment providing the polluting load of the screenings is taken into account in the design.

5.3.3 Disposal of Screenings

The problems of screenings disposal at sea outfalls are similar to those at a sewage treatment works but with the added complication that the treatment works of outfalls are usually in public areas thereby making difficult the inoffensive removal of screenings from site. This may be remedied by maceration of screenings and return to flow. One of the main objections against this is that maceration of large solids does not reduce the problem of objectionable scum or slick formation in the sea. Osorio(68) in the discussions following his paper stated that macerated material such as plastics, rubber, rags and wood can float, is frequently recognisable and inevitably causes the water to appear dirty. He added that if fine screens and complete removal of screenings are necessary to obtain public acceptance of an outfall scheme (as opposed to a treatment works) then they are justifiable financially. It is considered(146) that the use of flotation units in combination with macerators and return to flow (or comminution) offers a combination capable of largely eliminating the risk of visual nuisance at a reasonable cost. In this system macerated screenings are discharged to a short period retention tank where the floating matter can be removed for alternative disposal. The settleable solids are removed from the tank by a macerator pump and returned to the sewage flow for conveyance to sea.

It is generally necessary to give screenings some form of treatment prior to removal from site or dispose them at the head of the outfall by incineration. Screenings may be pressed and then transported in bags or closed skips to the disposal location, or as at Blackpool, the screenings can be macerated, discharged to a holding tank and removed by tanker to lagoons.

6. PILOT PLANT

6.1 GENERAL

The ideal sewage treatment works for undertaking pilot plant tests would be one with an elevated inlet works to which the sewage flow discharges by gravity or possibly to which it is lifted by screw pumps; where there are facilities for diverting flow to the pilot plant situated at ground level, at the same time ensuring that the proportioned flow to the pilot plant is truly representative of the whole, and where the sewage does not contain a high proportion of trade wastes particularly from industries which could affect the nature and quantity of screenings.

Whilst such a works may exist finding one to fit such exacting requirements could prove to be difficult. If, however, screens are considered as to form two basic groups then the problem is eased. The two groups being coarse screens and fine and special screens. The first group of screens are normally installed in channels with little special civil engineering work required for their installation, whilst the second group are normally installed in purposely constructed chambers. The efficiency of the first group of screens is also greatly effected by the extent to which the sewage is pumped and the type of pumping; whilst this is not so critical with the second group. Hence the pilot plant requirements for each group are in themselves less exacting than the requirements for a single pilot plant.

6.2 COARSE SCREENS

The screens of this group are normally designed to be installed in a channel. Therefore the ideal location for a pilot plant for this group would be the by-pass channel at the inlet to a medium to large sewage treatment works. This would reduce the amount of civil and mechanical engineering required to produce the pilot plant; whilst ensuring that a proportional flow could be diverted to the test screen without pumping or the use of syphons which in turn could give problems with ensuring that the proportional flow is truly representative of the whole. A false invert would have to be laid in the by-pass channel to ensure that back-watering of the test screen did not occur and also to enable flow through the pilot plant to be measured and controlled by a flume. Regulation of the flow entering the pilot plant would depend on the configuration of the actual inlet works chosen but this should be possible by use of the penstocks normally found at the inlet. It would be necessary within the pilot plant to allow for the installation of a fine screen in the form of a vertical plate downstream of the test screen in order to measure its efficiency. The pilot plant installation should be designed so as to allow the testing of any type of coarse screen but the first test screen should be a vertical straight bar screen so designed that the bar spacings could be altered and even the bars themselves replaced with ones of a different cross section.

The principle areas of investigation for this pilot plant should be:-

(i) to determine the optimum bar spacing to ensure adequate protection of downstream treatment units whilst minimising the quantity of screenings.

(ii) to determine the effect of bar shape on screen performance

(iii) to investigate the cost effectiveness of differnt types of screen

6.3 FINE AND SPECIAL SCREENS

Whilst it is important for the pilot plant for this group of screens to ensure that the flow to the plant is representative of the normal sewage flow to the works the exact nature of the screenings does not have the same effect in the performance or efficiency of the screen as for coarse screens. With this group sewage could be diverted to the pilot plant from the inlet works using a submersible pump providing adequate precautions are taken with regard to the nature of the diverted flow. The requirements for a works for this type of pilot plant is therefore a less onerous than that for the first group the only major criterion being with regard to industrial wastes.

The form of this pilot plant would be similar to that used for micro-screen trials, with a small screen say in the case of a fine screen 1m wide x 1m diameter mounted in a steel tank. Sewage would enter the tank through a baffled inlet, being pumped from the main inlet to the works by a small submersible pump. It could flow through the pilot screen and the screened sewage would then flow to the outlet, through a flow measuring tank and then back into the inlet works. Screenings and washwater would pass to a hopper with facilities for inspecting the collected solids before discharge also beck to the inlet works. With flow to the unit being pumped it would be necessary to include a facility for flow control and this could be accomplished by providing an overflow line, incorporating a sluice valve, situated at the upstream end of the tank. By operating the valve the quantity of sewage entering the overflow line and therefore by-passing the screen could be regulated. If the base of the tank containing the test screen is well below the underside of the test screen problems could occur with a build up of solids resulting from the tank acting as a settling chamber. It is therefore important that the base of the tank is as close as possible to the underside level of the test screen. In this way there would be very little area in which solids could settle out. As a precaution on this plant an emergency overflow should also be provided which would come into operation if say the mesh or a fine screen became completely blinded. The principle aims of this pilot plant should be:

(i) to investigate the blinding of fine screens and optimise the operation of these screens

(ii) to derive a theoretical relationship linking all the viariables in the design of fine screens

(iii) to evaluate the performance of special screens particularly in relation to the removal of COD, BOD and suspended solids

(iv) to investigate the cost effectiveness of different types of fine and special screen.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

7.1.1 Screenings' Characteristics

The largest single problem identified by the questionnaire survey (apart from mechanical problems) is the overloading of the screenings installations at times of storm. Of the 106 works surveyed 14 reported this problem. This appears to show a lack of appreiciation by designers of relatively large volumes of screenings discharged to a works at times of storm.

No conclusion can be drawn regarding the optimum bar spacing for screens at sewage treatment works. Conditions vary greatly with respect to flow, strength of sewage, nature of trade wastes, types of treatment and types of treatment plant. Therefore, each screenings installation has to be individually designed according to the condition at that installation. Modern UK practice with respect to coarse screens is generally to adopt a 20mm bar opening size.

Due to the highly variable nature of screenings, it has been impossible to reveal any trend in the composition of screenings. It is considered that the amount of rags in screenings is increasing with the increasing use of disposable cloths. As more synthetic fibres are used in cloths the proportion of synthetic fibres in screenings would also be expected to increase. An increase in the amount of plastics in refuse has been forecast and there seems no reason to suppose that a similar trend will not be apparent for screenings. The increase in use of domestic garbage grinders could also influence the amount and nature of screenings.

7.1.2 Coarse Screens

Hand raked screens require cleaning at least daily and frequently up to three times a day. They easily become overloaded in times of storm.

It is likely that the disadvantage of the daily cleaning required for hand raked screens would outweigh any advantage gained by installing a screen to protect the equipment at an installation (i.e. remote pumping stations and sewage works) being fed by means of 150 to

225mm diameter sewers and which installations would otherwise only require weekly attendance.

It is common in the design of coarse screens to make the leading edge of the bars slightly wider than the trailing edge, which minimises the possibility of screen jamming. This does not apply to back-raked screens when round or parallel bars are used.

The curved bar scrben has the advantages that all moving parts are above the level of the sewage (thereby easing maintenance) and it has a larger area of screen per depth of flow than a straight bar screen. However, screenings cannot be lifted a large distance above coping level and this should be considered if any subsequent screenings treatment is intended. Problems may be encountered in setting-up a curved bar screen with small bar openings on site if the screen and raking mechanism are mounted separately on the concrete sub-structure. A reasonable minimum bar opening size for a curved bar screen appears to be 12mm in view of the tolerances required in manufacture and installation.

Grab screens or continually raked screens set at approximately 70^{o} to the horizontal have an advantage over a vertical screen in that the screenings collection trough or conveyor can be positioned under the rake thus dispensing with the need for a hinged discharge plate. It has also been shown that the modification of a screen from the vertical to inclined has reduced jamming of screens by solids. However, inclined screens take up more space than vertical screens.

Screen discharge plates, if set at a minimum of 60^{o} to the horizontal, have been found to be self-cleaning.

Continuously chain raked screens have an advantage in that increased screen cleaning may easily be effected by increasing the speed of the chain drive or by adding more rakes to the chain. However, this type of screen has moving parts below sewage level resulting in wear due to grit and is difficult to maintain.

The back raked screen because its raking action is more positive especially at the bottom of the screen, is infrequently jammed by solids and cleaning is generally more efficient than with the other types of screen. Due to their construction particular types of this screen constructed of bars fixed at the bottom and supported by the travelling rakes are liable to distortion thus allowing larger solids to pass. Any solids remaining on the raking tines may be washed off by the sewage flow downstream of the screen as the rake is cleaned. This effect can be minimised by proper setting of the rake wiper blades.

Current design practice is to limit the velocity of flow through coarse bar screens to $0.6m^3/s$ for sewage flows of up to 3 DWF and to 1 m/s for flows above this figure. The minimum flow is limited to 0.45 m/s to prevent the deposition of grit.

The provision of a lightweight building to cover screenings installation protects mechanical and electrical equipment and eases maintenance.

7.1.3 Fine Screens

The present level of knowledge of the application of fine screens for the screening of sewage is insufficient to ensure economic design and trouble free operation without problems due to clogging. There appears to be an urgent need for research into this aspect of screening practice.

The fine screening of sewage is practiced at a number of works in order to alleviate problems in subsequent treatment processes due to trade wastes. The fact that rotary drum screens are generally cleaner in operation than normal bar screens is an added advantage. The use of fine screens for this purpose is not likely to increase until there is a further understanding of the action of fine screens in screening crude sewage. Difficulties may be experienced in the cleaning of fine screens if the backwash water pressure is less than 2.0 bar.

7.1.4 Special Screens

The use of the various types of special screen is still in its infancy in this country. There is a need for more operational data before their effectiveness in the field of sewage treatment can be fully evaluated.

7.1.5 Treatment of Screenings

The practice of comminution or of maceration and return to sewage flow may result in 'balling-up' of fibrous solids and the blocking of pipework and valves; the formation of scum in sludge digesters; relatively high levels of non-degredable matter in the sludge; and the cracking of plates in the sludge filter presses. This practice may also aggrevate problems with floating material in both primary and secondary settlement tanks. The presence of trade effluents in the raw sewage may increase the possibility of the above difficulties occurring.

Although from the survey 'balling-up' appears to be more a difficulty encountered from the use of comminutors than macerators, it has not been possible due to its recent introduction to evaluate the effect of the new narrow slot comminutor with 7mm wide slots.

Comminutors have the advantage of cutting up the sewage solids within the sewage flow over the prior separation required for maceration although due to the intricate chamber shape required civil engineering costs tend to be higher for the installation of comminutors.

Operating experiences in this country tend to show that the ram press works satisfactorily on coarse screenings although problems have been encountered on screenings containing large amounts of unbroken organic sewage solids. With the other types of press experience is limited. The screw press appears to accept fine screenings satisfactorily as does the Screezer which is in effect a combined fine screen and press.

The removal of screenings from carrier water is an aspect of screenings treatment where there are few operational data available. There is a need for research work on the various methods to allow this type of treatment to be fully evaluated. There is a need for more development work and operating data before centrifuging can be completely evaluated.

7.1.6 Disposal of Screenings

The burial of screenings is an objectionable task. Rodents and birds may be attracted to the burial site thus causing possible health risks.

It is considered that composting could be a satisfactory alternative to burial at small works providing it is carried out correctly, though as with burial, rodents could be a problem. There is a need for further research work to determine the optimum composting conditions for this country.

The proper incineration of screenings is inoffensive, hygienic and results in a residue which can be easily disposed of. The choice between incineration in a separate screenings incinerator or in a municipal refuse incinerator is mainly dependent on operating costs and location.

The dewatering of screenings prior to incineration reduces fuel costs, reduces the size of the incinerator, and allows the excess screenings in times of storm to be stored less offensively before incineration.

The choise between manually and automatically fed incinerators depends on the size of the works.

The incineration of screenings with sewage sludge does not appear to be practiced in this country at the present time but it is a method worthy of further evaluation.

7.1.7 Costs

The capital cost of screening equipment vary considerably. Any complete economic evaluation of screening methods must take into account civil and mechanical/electrical capital costs, and operating costs.

7.2 RECOMMENDATIONS

If pilot scale tests are impossible, Table 3.1 and Unit Processes - Preliminary Processes[13] should be used as a guide to the average amounts of screenings which can be expected at screenings installations. Figure 2.3 should be used to estimate the amounts at peak flow.

It is considered that hand raked screens should only be installed at very small works with a DWF of less than $1000m^3/d$. At least daily attendance is required and a minimum opening of 50mm is suggested to minimise organic solids in the screenings.

Consideration should be given to omitting hand raked screens at installations which would not otherwise require daily maintenance and which are fed by small sewers up to 225mm diameter.

Consideration should be given to the abandoning of hand raked coarse screens to protect fine screens in favour of mechanical coarse screens.

Front raked mechanical screens should have bars with the leading edge slightly wider than the trailing edge to minimise jamming by solids.

The minimum bar opening size for curved bar screens should be 12mm.

Installation with mechanically raked screens should have a minimum of two units with consideration given to providing stand-by capacity based on 3 DWF and a by-pass channel in case of screen failure. It is also advisable to provide penstocks upstream and downstream of the screens in order to isolate a screen from the flow to allow access for maintenance.

It is considered that the velocity of flow through mechanically raked bar screens should be a maximum of 0.6m/s for flows of up to 3 DWF and 1 m/s above this flow; the minimum velocity should be 0.45 m/s.

Screenings installations should be designed to deal with the daily peak volume of screenings but consideration should also be given to handling the additional volume of screenings anticipated at times of storm.

Screening chambers should be designed to ensure that velocities through the chambers are self-cleansing and that the hydraulic head loss through the screen is not likely to cause surcharing of the incoming sewer and possible premature operation of upstream storm overflow.

Screenings installations should be covered with a lightweight building to protect equipment and ease maintenance.

Electric motors to screens installed in screen houses or chambers shall be fitted with anti-condensation heaters.

At large works (pop. served $>$150 000) consideration should be given to installing two sets of screens, the upstream set having openings of 100mm to 150mm and being installed basically to deal with the various large objects which are found in sewerage systems with large diameter sewers. The second set should have openings dependent on the minimum size of solids which need to be removed.

Due to the present lack of knowledge regarding the fine screening of crude sewage pilot scale tests should be carried out where possible prior to designing a fine screen installation.

In view of the operational difficulties often associated with works where comminution or maceration and return to flow have been installed, consideration should be given to using alternative methods of screenings treatment where possible. However, at unmanned works treating almost entirely sewage of domestic origin, the low levels of maintenance and inspection associated with these processes would probably outweigh their disadvantages.

Where comminutors or macerators are installed the distance from the inlet works to the primary sedimentation tanks should be minimised to lower the possibility of 'balling up'.

The burial of screenings should only be practised at very small works. An alternative could be transportation to a controlled landfill site where the screenings should be buried according to the code of practice for controlled tipping.

If screenings burial on site is carried out they should be covered as soon as possible and with a minimum of 0.5m of top soil.

For optimal incineration screenings should be dewatered to a moisture content of about 70% prior to incineration.

7.3 SUGGESTIONS FOR FURTHER WORK

During the course of this research project it has become evident that in certain areas there is a general lack of knowledge. In the pilot plant study and recommendations attention has been drawn to these areas. It is considered that certain aspects of the screenings process are more important than others and that there is more urgent need for information in some areas than others. Therefore, it is suggested that immediate research is concentrated in the following areas:

1. Investigations into the cost effectiveness of alternative methods of screenings disposal;

2. research into the performance of fine screens in screening raw sewage in order to determine their effectiveness and the design parameters necessary to ensure economic operation and eliminate clogging;

3. investigations into the optimum bar spacing for coarse screens to ensure adequate protection for downstream treatment units whilst minimising the quantity of screenings.

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APPENDIX A

SAMPLING AND ANALYSIS OF SCREENINGS

SAMPLING

No standard methods of sampling screenings were revealed during the project and the following, based on those used for sampling refuse, are suggested as possible methods to adopt should it be found necessary to collect samples for testing.

Collect in a suitable container about 24 kg of screenings and divide by successive quartering until a representative 1.5 kg sample is obtained, or collect a representative sample as the screenings are discharged from the screen. Both methods clearly yield only a subjective representative sample. The samples should then be placed in a perforated container until all free water has drained away.

ANALYSIS

No standard methods of analysis were revealed during the project and again the following are suggested as suitable methods of consideration if it is found necessary to test screenings.

Moisture Content

Take a 1.5 kg sample and divide it into three equal parts and analyse each sample separately. Determine the weight of each sample and evaporate nearly to dryness on a steam bath. Complete drying in an oven at 105°C for approximately one hour. Cool in a dessicator and re-weigh. Repeat heating at 105°C for 15 minute periods until successive weighings do not differ by more than five grammes. Moisture content can then be calculated in the following manner:

$$\text{moisture content} = \frac{Ww - Wd}{Ww} \times 100\%$$

where Ww = weight of wet screenings
Wd = weight of dried screenings

Volatile Matter

Ignite the residue from the determination of the moisture content, at first gently and then at a temperature of about 700^{o}C for half an hour. Cool in a dessicator and re-weigh. Repeat the ignition if unburnt carbonaceous material remains. Volatile matter can then be calculated in the following matter:

$$\text{Volatile matter content} = \frac{Wd - Wi}{Wd} \times 100\%$$

Where Wd = weight of dried screenings
Wi = weight of ignited screenings

Calorific Value

Due to the difficulty in obtaining representative samples of screenings and the small sample size of bomb calorimeters, a suitably large sample of screenings should be homogenised. The calorific values of a number of aliquots of the homogenised screenings should then be determined using a bomb calorimeter and the mean value calculated

Other Analyses

Particulary in assessing the performance of fine screens, it is necessary to determine BOD, suspended solids and settleable solids concentrations. These analyses should be carried out in accordance with the procedures in 'Analysis of Raw, Potable and Wastewaters', H.M.S.O., 1972.

Efficiency

The efficiency of fine screens should be expressed as the percentage of dry solids removed of the total of dry solids. The total dry solids is the sum of the dry solids removed and the suspended solids in the sewage after screening.

APPENDIX B

COMPUTER PROGRAM

In view of the large number of references discovered during this research project it was decided to use a computer based file handling and reporting package to enable details of each reference to be stored on the Sheffield City Polytechnic Computer, an I.B.M. 370/135. The program package chosen is called MARK IV and is marketed by Informatics Inc., of California. It is widely used throughout the world and was chosen for this project because it is easy for non-programming personnel to select data from file and to present it in a satisfactory manner.

The following details for each reference were coded and punches onto 80 column punch cards before being stored on disk files:

(i) Author
(ii) Title
(iii) Source
(iv) Abstract
(v) Key Words
(vi) Standard of Reference i.e. poor, good or important
(vii) Reference Number

The computer program was then used to produce reports listing references in different formats depending upon the current needs of the project. The principle formats used were

(a) references arranged in groups depending upon key work; and

(b) references listed with authors in alphabetical order.

The first format was of great assistance when the literature survey was being compiled and the second was used when compiling the list of references given in the main body of this thesis.

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RP.234 Separation Treatment and Disposal of Screenings

Questionnaire

1. Name of Works	Name of person for further information	
2. Flow to Works (M^3/day or state units)	a) Maximum Flows:-	
	b) D.W.F. :-	
3. Percentage Trade Effluent (Vol/Vol D.W.F)		
4. Main types of Industry		
5. Any Control on large Solids from Industry		
6. Screen Plant	a) Separation	Screens <20mm 20-35mm >35mm Comminutors *
		No. and size of Units:-
	b) Treatment	Maceration/Pressing/Other/None *
	c) Disposal	Burial/Return to Flow/ Incinerate/Other *
7. Basic Sewage/Sludge Treatment Process		
8. Problems associated with the Screening installation		
9. Are records available? (Volume, density, etc.) (No.of dumper skips/week)		
10. Remarks		

* Delete where applicable, if "other" please state