SOME DESIGN CRITERIA FOR REDUCING DUST WHEN HANDLING CLAY BONDED SAND

F. M. Shaw
British Cast Iron Research Association
Birmingham, England

ABSTRACT

This paper discusses methods whereby dust emissions may be reduced and exhaust control facilitated by consideration of dust reducing measures during the design of the foundry. The quantity of dust emitted during transport and handling of molding sand is closely related to the moisture content of the sand. Several ways are available to restore the moist condition as soon as possible after shakeout:

1. A small muller may be added immediately after shakeout.
2. Water may be added directly to the sand on the conveyor.
3. Excess moist system sand may be produced, much of which is mixed with dry sand at shakeout and recycled (Schumacher Process).

Material handling systems should be designed to minimize dust emissions:

1. Conveyor sizes should be selected to minimize spillage.
2. Belt speeds should be properly set and maximum design inclinations should not be exceeded.
3. Hopper discharges onto belts should be properly sealed.
4. Where belt enclosures are used, they should be easily removable and replaceable.
5. Bucket elevators should be sized large enough and operated at the proper speed.

Pneumatic conveying provides good system flexibility while facilitating dust control.

Vacuum cleaning systems provide for good housekeeping and cleanup of small sand spills.

The difficulty of controlling dust from shakeout is a function of the degree of mechanization and/or automation used to load and unload molding flasks. Manipulators have been used successfully allowing remote control of the shakeout operation from an enclosed booth.

INTRODUCTION

Foundries have a reputation for being dirty and unpleasant places to work in, and this image is to some extent the result of the amount of dust and fume present in the atmosphere. To improve working conditions, it is imperative that foundries pay adequate attention to dust control, but improvement may be difficult because of the design and layout of existing equipment.

It is important that, when equipment and systems are designed and installed in foundries, proper consideration be given to dust control. A well designed plant from an environmental aspect will be higher in capital cost than one designed solely to produce acceptable castings, and this extra cost can only be justified when it makes possible the provision of effective dust control. The objectives of good design and equipment selection should be to reduce or eliminate the need for dust control, but when this is not possible, dust control should be at least capable of being applied effectively. The major point to be made is that foundry dust control does not consist of waiting for dust to be generated and then fitting an exhaust hood to remove it; it should consist of designing the foundry to make it as dust-free as possible in the first place. Since the handling of clay bonded sand is a major source of dust in foundries this paper considers some ways of reducing dust generation by good plant design.

DESIGN OF PROCESSES WHICH GENERATE DUST

Effect of Moisture on Sand Dustiness

The amount of dust generated when sand is disturbed depends on its moisture content; dry clay-bonded sands generate obvious dust clouds whereas no dust is generated by wet clay-bonded sand. Work carried out at BCIRA has shown that foundry sand containing not less than one-third of its working moisture level, which is evenly distributed, is unlikely to be a source of appreciable dust (1). Figure 1 shows the relation found between the amount of dust generated and moisture content of a typical green sand. The evenness of distribution is important, as sand containing an average of 2 percent moisture can contain pockets of wet and dry sand and the latter will generate dust if disturbed.

The practical implication of this work is that molding sand does not give rise to dust during its passage from the muller right up to the pouring station. It is only when sand in the molding condition is allowed to dry out that it becomes a source of dust. If the sand conveying systems allow sand to drop onto the floor from belts, transfer points, etc., the sand will dry out and be disturbed by traffic (human and mechanical), resulting in airborne dust.

Dust is always generated at the shakeout and from this operation onwards, therefore, the object should be to get sufficient, well distributed moisture back into the sand as quickly as possible to suppress the dust.

Sand Handling Design

Use of an Auxiliary Muller--

One method of introducing water is to utilize an auxiliary continuous pan muller immediately after the shakeout as shown in Figure 2. The muller is not intended to develop the "green" strength of the sand but merely to

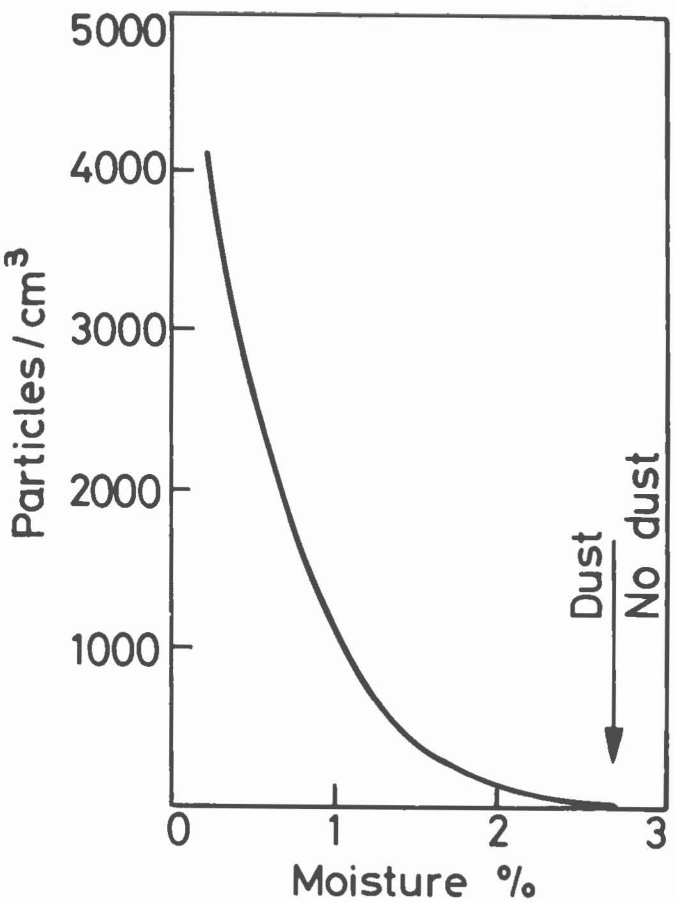

Figure 1. Dust generated by typical used green sand (1).

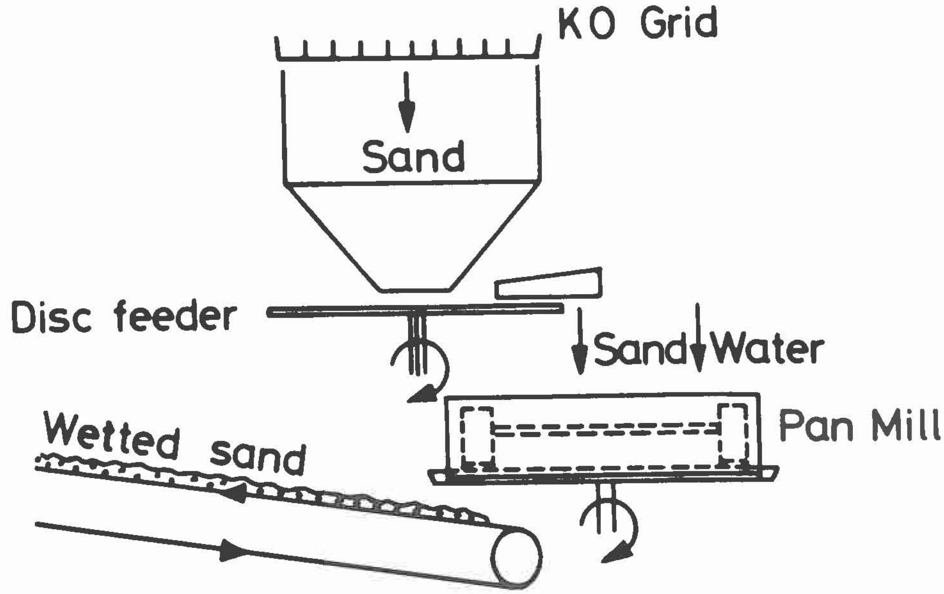

Figure 2. Use of Pan mill at knockout.

distribute sufficient water into the sand to make it non-dusting. In spite of the obvious disadvantages of such a system, e.g., the extra equipment required, more maintenance, increased space requirements, tramp iron problems, etc., such equipment has been installed and used successfully. Not only is dusting suppressed, but a useful degree of sand-cooling is obtained as the moisture can partially evaporate and thus cool the sand in subsequent parts of the sand plant (particularly the screen) (2). An aerator can serve a similar purpose and may be easier to accommodate.

Water Additions to Sand on Conveyor Belts--
Water added to a shakeout discharge conveyor belt should be added on the basis of the sand flow, its temperature, and its moisture content. In practice, the sand temperature after the shakeout provides a sufficiently accurate indication of the moisture content and thus the amount of water to be added can be based on sand throughput and temperature only. Various units for adding water to sand belts are available; throughput is based on the measurement of sand height by means of a mechanical arm and temperature is measured by one or more thermocouples trailing in the sand. Water is added by sprays over the belt (Figure 3) actuated from a control box which determines, according to the sand flow and temperature, the amount of water to be added (3). Water added in this manner is not evenly distributed and dry pockets will result, but they can be reduced by ploughs or fingers mounted over the belt to mix the sand and added water; these, however, can also act as sources of dust.

The Addition of Damp Sand--
An alternative method of adding water indirectly to shakeout sand is by addition of prepared molding sand. An excess of sand may be deliberately mulled greater than is needed for mold making, as in the Schumacher process. A layout of a sand plant using this system is shown in Figure 4. Depending

on the metal:sand ratio, extra sand is mulled amounting to about the same as that required by the molding line. The surplus sand is diverted from the muller into the return sand system. The shakeout sand is thus buried in damp non-dusting sand and, until disturbed, no dust will be generated. The two sands are mixed at the earliest possible moment after shakeout. Normally magnetic separation is first required after which mixing is accomplished by one or more aerators mounted over the sand belt. Note that even distribution of moisture in the mixed sand is essential, and equipment to ensure that the sand is well-mixed is a necessary part of the dust suppression system. An aerator is shown after a magnetic separator and it would be expected that dust would be suppressed after this point. As with other methods of dust suppression, extra costs are involved. In this system, the extra costs are due to the need for increasing the mulling capacity and providing the larger belts required. It is also essential that mulled sand be available for addition to the shakeout sand during the whole period that shakeout takes place. The results of "before" and "after" airborne-dust surveys in foundries having installed the Schumacher or a similar system are awaited with interest. It should be noted that a mulled sand addition is intended not only to reduce dust but also to provide cool sand at the molding line.

Clay and Coal Dust Additions--
The addition of dry coal dust and clay to a muller or to sand on a belt generates dust. Where possible the addition of both materials should be made as a slurry. The use of slurry additions is possible when:

1. The amount of water added as an unavoidable component of the slurry is not in excess of that required to bring the sand up to molding moisture level. In practice this means that the sand-to-metal ratio needs to be low.

2. A continuously agitated slurry tank is installed with a recirculating main to prevent settling out of the slurry.

3. A non-gelling clay is used, e.g., calcium montmorillonite, otherwise the amount of clay in the slurry is restricted to about 6 percent by weight.

The dustless addition of clay has a further advantage in that "live" clay is not exhausted to the dust collector where, if it is of the usual wet design, it results in a slurry which cannot be settled and is difficult to dispose of.

Belt Conveyors--
A major reason why most mechanized foundries quickly become dirty is that sand is spilled from belt conveyors and falls onto gangways, overhead walkways, etc. Even if the sand is dustless as it falls from the conveyor it quickly dries out. Operators walk on the dried sand and transport vehicles drive over it and the result is the generation of dust which spreads throughout the foundry and collects on all horizontal or near-horizontal surfaces. Removal of this deposited dust by non-vacuum sweeping methods gives rise to more airborne dust and often results in part of it being

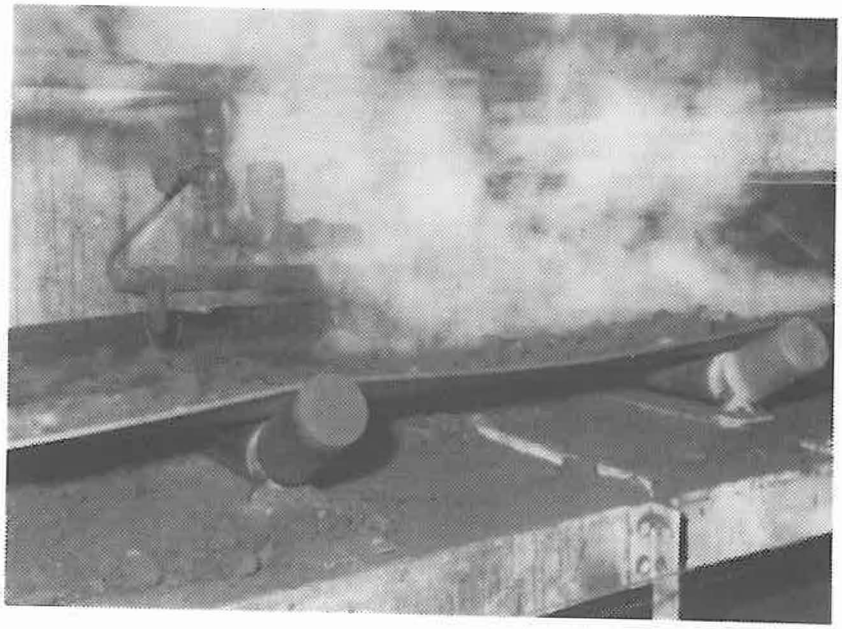

Figure 3. Water additions to sand on knockout belt.

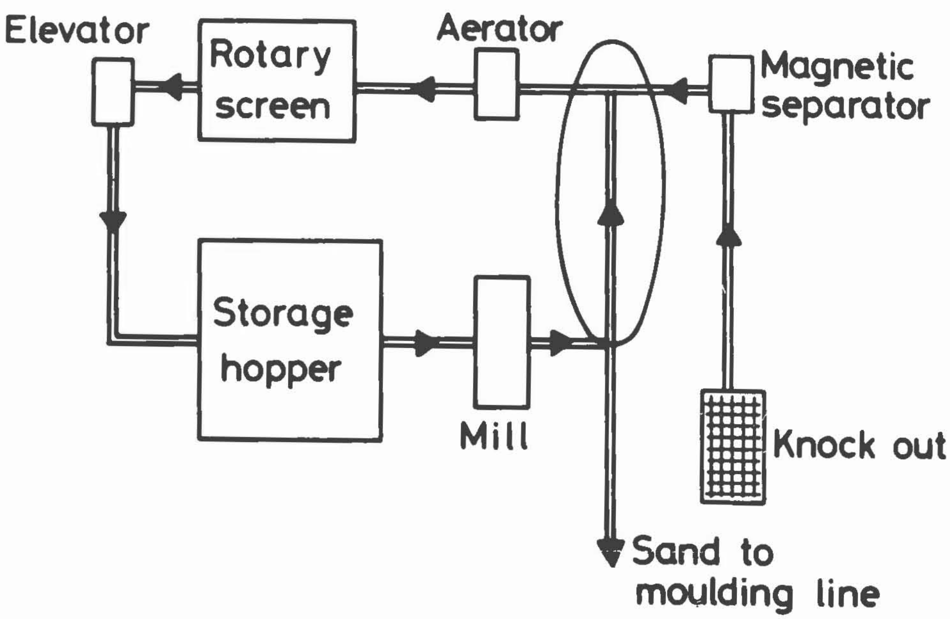

Figure 4. Schumacher system.

Table 1. Sand-loading capacities of foundry belts in metric ton/hr.

Belt width, mm	Belt trough angle	Molding sand (800-1040 kg/m^3) Belt speed, m/s						Knockout sand (1040-1200 kg/m^3) Belt speed, m/s						Dry silica sand (1280-1760 kg/m^3) Belt speed, m/s					
		0.25	0.5	0.75	1	1.25	1.5	0.25	0.5	0.75	1	1.25	1.5	0.25	0.5	0.75	1	1.25	1.5
460	20°	12	23	36	47	59	71	17	36	53	71	88	105	23	47	71	95	118	141
	27°																		
	35°	NOT PRODUCED FOR THIS BELT SIZE																	
	45°																		
600	20°	23	47	71	95	118	141	36	71	105	141	177	212	47	95	141	189	238	284
	27°	27	55	81	109	136	163	41	81	123	164	204	245	55	109	143	217	272	328
	35°	31	61	91	123	152	183	46	92	137	183	229	275	61	123	183	244	305	367
	45°	35	63	103	136	171	205	51	103	153	205	256	307	68	136	204	272	340	407
750	20°	40	79	119	158	198	237	59	119	178	237	296	356	79	158	237	316	394	474
	27°	46	90	136	182	227	272	68	136	204	272	340	409	90	182	272	363	454	544
	35°	51	101	151	201	252	303	75	151	227	303	378	454	101	201	303	403	505	608
	45°	56	111	168	223	279	335	83	168	251	335	420	503	112	223	334	446	558	670
900	20°	59	119	178	238	297	356	88	178	267	356	445	534	119	238	356	475	593	712
	27°	88	136	204	272	339	407	102	204	306	407	510	612	136	272	407	544	680	816
	35°	75	150	226	301	377	452	114	226	339	452	565	678	150	301	452	603	753	903
	45°	82	166	249	331	414	497	124	248	375	497	622	746	166	330	498	663	828	994
1050	20°	83	166	250	333	417	499	125	250	375	499	624	750	166	333	499	668	832	999
	27°	96	191	285	380	476	571	142	285	428	571	713	856	191	380	571	760	951	1141
	35°	106	210	316	421	525	631	158	316	474	631	789	947	210	421	631	841	1052	1263
	45°	115	231	346	460	575	691	173	346	518	691	862	1036	231	460	691	921	1151	1381

dislodged from one place only to be deposited again in another.

A reduction of belt spillage depends primarily on belt design. For the type of conveyor used most in foundries, there is sufficient data available to enable the belt and its ancillaries to be economically designed (4). Table 1 gives recommended belt sizes for various capacities of belt. Capacities vary for different sands because of varying bulk densities, e.g., sand in the molding condition is less dense than shakeout sand, and a belt will, therefore, carry a lower flow of molding sand than of shakeout sand.

Some design points which need to be considered to reduce spillage are given below:

1. A belt must be designed for the maximum capacity required of it even if this is only needed for short periods. Whenever possible surge hoppers should be used to even out sand surges and to allow for smaller and less expensive belts. In practice, the estimated peak loading is often taken as double the maximum sand flow needed for molding.

2. Troughed belts are normally run at speeds up to 1.5 m/sec (300 ft/min). Speeds above this make the operation of ploughs and magnetic separators less satisfactory.

3. The trough angle has been limited in the past to 20 degrees. The development of the nylon belt allows steeper angles - up to 45 degrees - to be used. The steeper the angle, the higher the carrying capacity of the belt and the lower the spillage for a given throughput.

4. Where flat belts are used or where troughed belts are run flat in some parts of the system (e.g., to allow ploughs to be fitted), the capacity of the belt should be taken as half that of the equivalent width of a 20 degree troughed belt, otherwise spillage will occur.

5. Belt inclination affects the amount of slipping and roll back which takes place. Excessive inclination leads to spillage and reduced belt capacity. The maximum belt inclination should be 17 degrees for shakeout sand carried by 20 degree troughed belts. Even at this angle there may be some difficulty with sand lumps rolling back down the belt and eventually falling off. It may be prudent, therefore, to restrict the maximum inclination to 15 degrees for shakeout sand and 18 degrees for prepared molding sand.

   Special belts with molded cross-bars and frilled edges forming a troughed section until the belt goes around a pulley, may be used at inclinations up to 50 degrees. Such belts may sometimes be used to supersede bucket elevators.

6. Belt cleaners should be used whenever sand sticks to the belt. If they are not, sand will be dislodged from the return strand of the belt and give rise to a secondary form of spillage. Figure 5 shows a static scraper, and Figure 6 a rotary cleaner driven by its own motor. A modified trough conveyor where the belt runs in guides to retain its trough configuration is shown in Figure 7. Covers to enclose the top are available which result in nearly complete enclosure.

7. Pulleys often build up with sand, and belt-wander results. Self-cleaning pulleys help to prevent this and one such design is shown in Figure 8. Belt-wander is one cause of sand spillage from conveyors.

8. The efficient sealing of hopper discharges onto belts reduces spillage. One method of sealing is shown in Figure 9. Poor hopper-to-belt sealing is a frequent cause of spillage, especially in underground pits where maintenance is unpleasant and often neglected.

9. Beneath hoppers, where rollers are subject to impact from sand falling on the belt, impact-resistant rollers are sometimes used. These also help to clean the underside of the belt.

10. The type of belt fastening used affects sand leakage. Only a vulcanized joint is leakproof and should be used in preference to mechanical belt fasteners.

Belt Enclosure--
Even with good design some spasmodic spillage of sand is likely to occur, especially from the underside of the return strand. It is possible to enclose a belt conveyor completely (Figure 10). The enclosure must be easily removable and replaceable for inspection and maintenance purposes. The system shown uses fabric stretched over a frame, but other systems are available.

Enclosure hinders the removal of spilled sand and some means of getting rid of it is necessary. This can be achieved by fitting shallow hoppers beneath the belt, equipped with nozzle outlets to which can be attached flexible exhaust tubes connected to a central vacuum-cleaning system.

Pneumatic Conveying--
Pneumatic conveying is a dust-free conveying system for all types of sand. Sand is conveyed by air pressure through small pipes which provide complete enclosure for the material being conveyed. Apart from being dustless (or at least very easily dust-controlled), pneumatic conveying allows complicated plant layouts and takes up little space. One possible layout is shown in Figure 11. The main advantage of the system apart from its cleanliness is the flexibility it provides in plant layout. Flexibility is not always possible with conveyor belts.

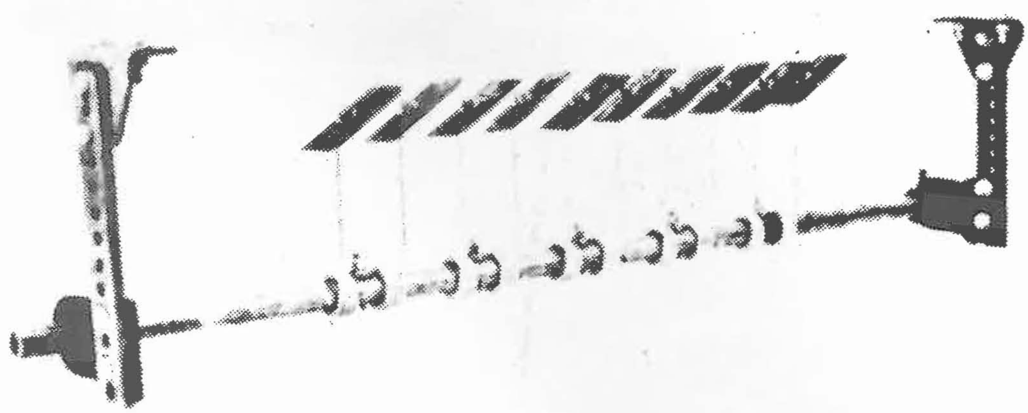

Figure 5. Stationary belt scraper.

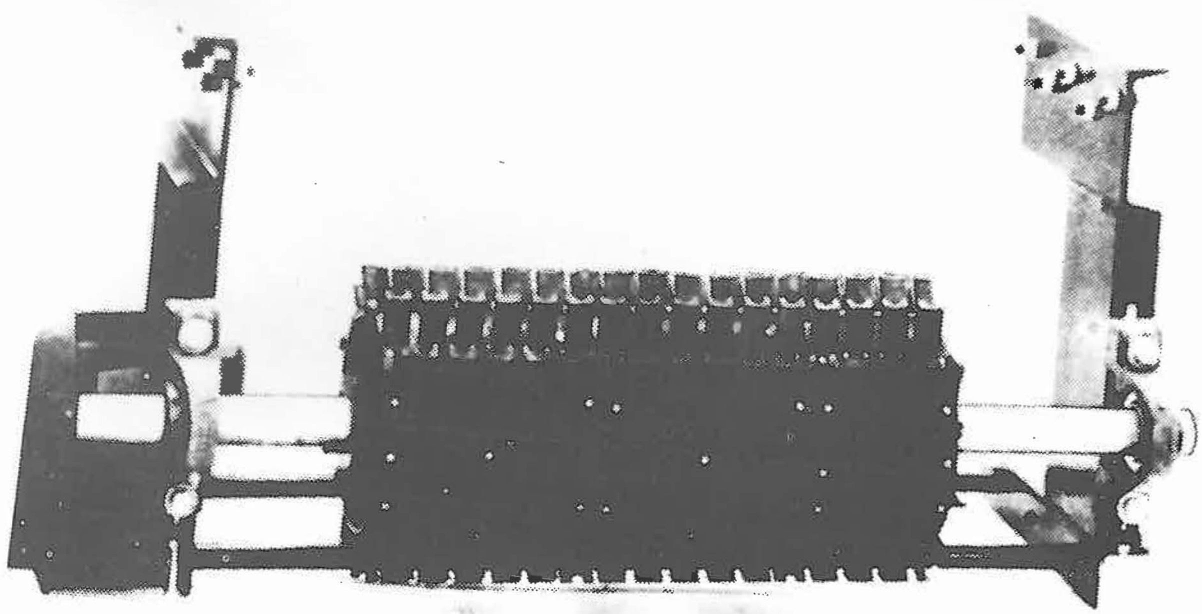

Figure 6. Rotary belt cleaner.

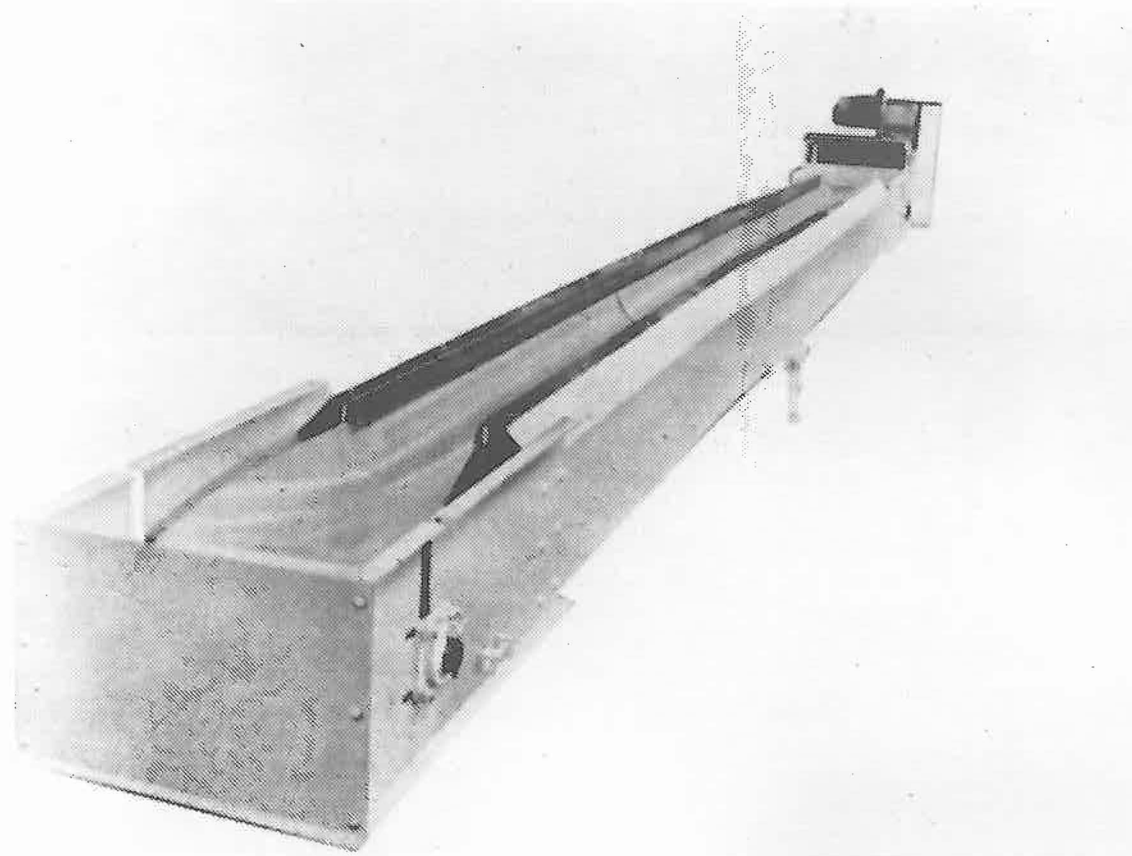

Figure 7. Formed trough conveyor.

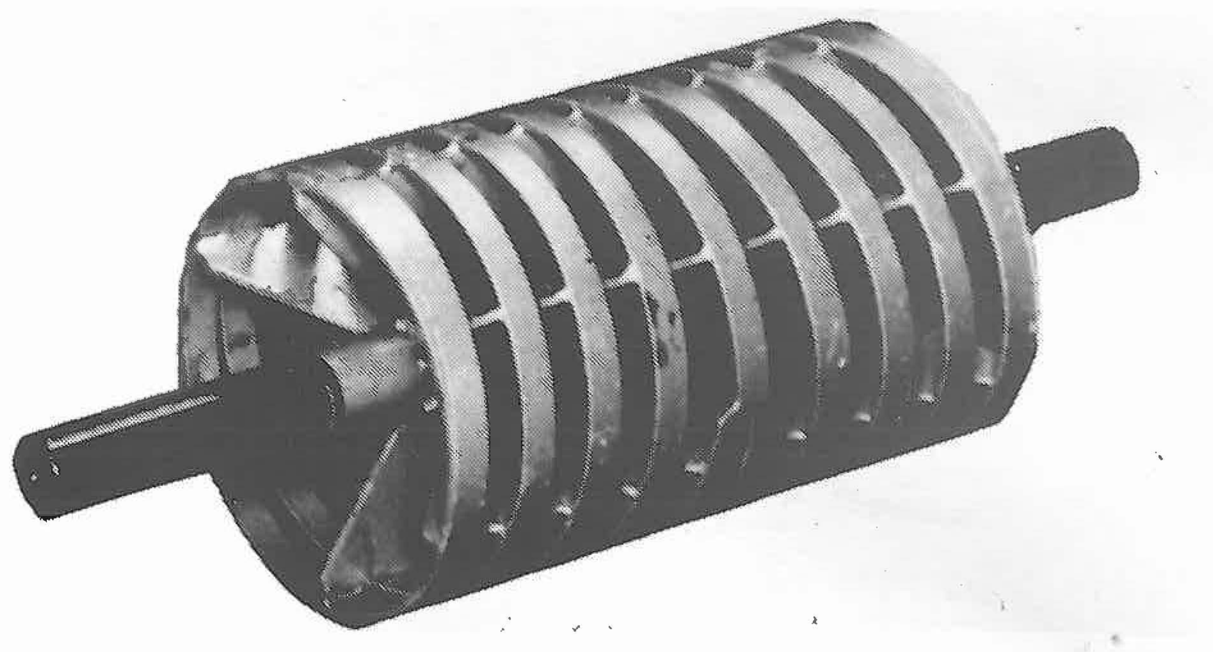

Figure 8. Self-cleaning pulley.

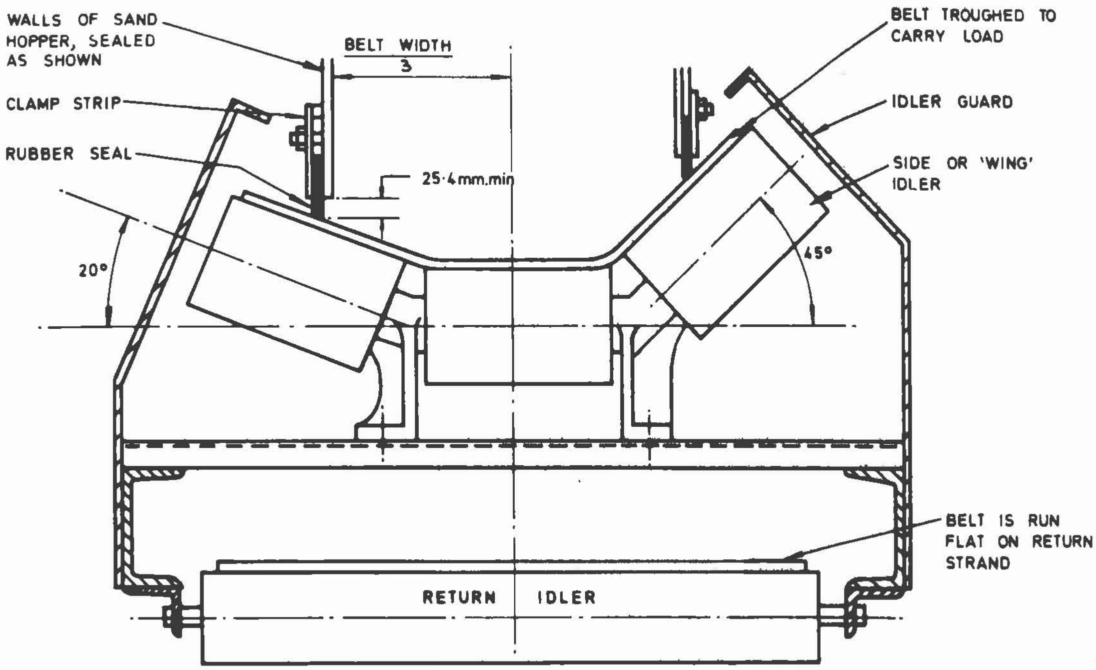

Figure 9. Section through conveyor showing a 20° and 45° troughing idler, chute, and sealing skirt with idler guard.

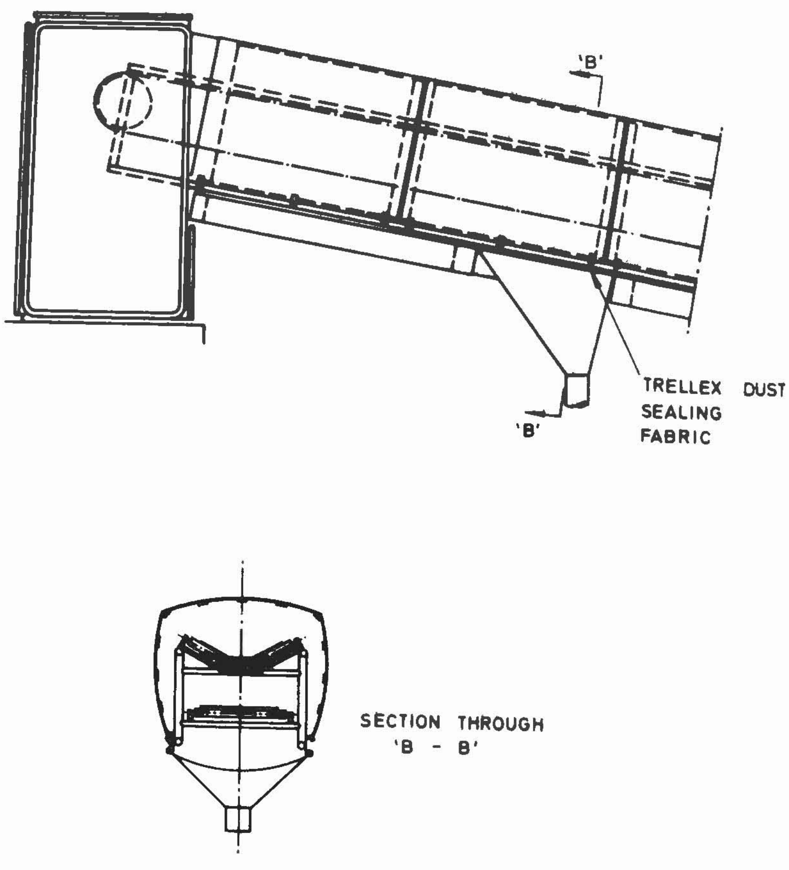

Figure 10. Enclosure of belt conveyor.

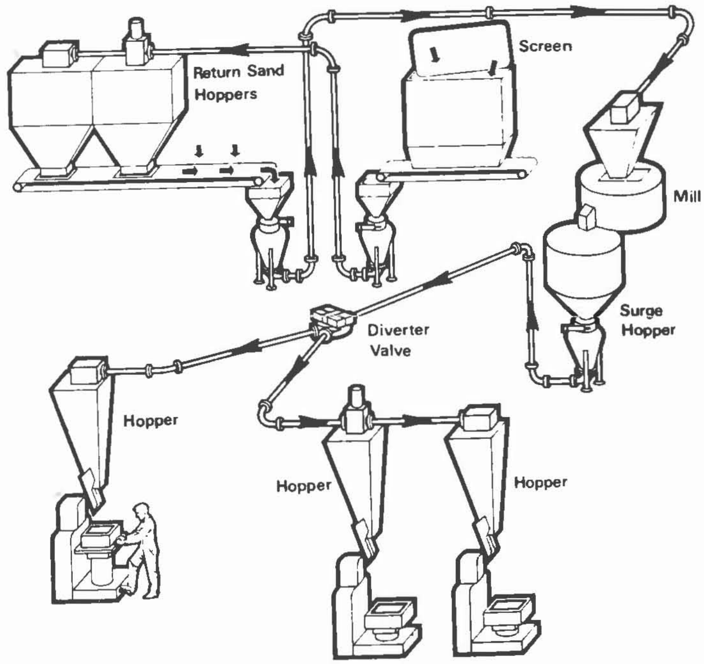

Figure 11. Pneumatic conveying of molding sand.

The disadvantages of pneumatic conveying are:

1. Power consumption. The conveying medium is air which is initially compressed to approximately 6.3 Kg/cm^2 (90 $lb/in.^2$). Depending on the vertical and horizontal distance of the sand conveyed, and number of bends in the conveyor, a power consumption of 3 - 5 kW per metric ton per hour capacity of sand conveyed can be expected. For example, to convey 20 t/hr of sand, approximately 80 kW will be needed at the compressor. A conveyor belt, in comparison, will only need some 11 kW or less for conveying sand at the same flow rate for a distance of 76m (250 ft) horizontally and 10m (33 ft) vertically.

2. Maintenance costs may be higher than for equivalent belt systems. This is because pipe bends and diverter valves wear out and the air compressor needed to supply the motive power needs more maintenance than the electric motors used on belt systems.

3. Capital cost is likely to be higher than for a conveyor belt system, unless spare compressor capacity already exists.

Bucket Elevators--
Bucket elevators are widely used to raise sand from one level to another. They are frequently underdesigned and sometimes run at the wrong speed; both faults cause spillage. The capacity of the elevator should be the maximum capacity ever required. If necessary, surge loads can be reduced by surge hoppers.

The capacity of the elevator should then be obtained by using the following formula (5):

$$\text{Capacity, kg/h} = \frac{66\ BVND}{P}$$

Where:
B = Bulk density, kg/m^3
V = Total bucket volume, m^3
N = Speed of head pulley, rev/min
D = Diameter of head pulley + 2 (belt thickness), m
P = Pitch of buckets on belt, m

The bulk density varies quite widely with the type and condition of sand (Table 2).

The fact that average bucket filling may be only 35 percent of total capacity has been allowed for in the capacity design formula. Wherever sand below a temperature of 100°C is being handled, nylon buckets are recommended instead of metal. The service life of nylon buckets is longer and sand sticking is less, thus providing additional capacity and reducing the possibility of spillage.

Table 2. Bulk density of foundry sand in various conditions.

Sand condition	Bulk density kg/m^3	Bulk density lb/ft^3
Molding sand	800-1040	55-65
Shakeout sand	1040-1200	65-75
Free-flowing silica sand	1280-1760	80-100
Zircon sand	2720	170

The speed of the top pulley should ensure that sand is not carried around again by the bucket (too high a speed) and does not fall back down the elevator (too low a speed). Both these faults reduce elevator capacity.

The correct speed is given by:

$$N = \frac{42.3}{\sqrt{D}}$$

Where:
N = rev/min of pulley
D = Diameter of pulley + 2 belt thicknesses + 1 bucket projection, m

Vacuum Cleaning Systems

Portable vacuum cleaning units or central suction systems are becoming more popular. They have the advantage that they can remove materials dustlessly even if it is dry sand. They are, however, not a replacement for good design of sand handling equipment.

Some buyers of cleaning systems have been disappointed because the units are unable to quickly remove large sand spills. Vacuum systems are not suitable for this purpose but they do provide a very useful means of cleaning up minor spillages and for removing dust from surfaces.

Shakeout

Once the mold reaches shakeout it is partially dry due to the metal poured into it. As soon as molds are broken open to remove the solidified castings, dust and steam are generated.

Thermal currents from the hot castings and sand will carry dust for considerable distances unless controlled. A decreasing number of foundries still shake out over large areas of the foundry floor. Generally speaking, production rates in such foundries are low and the dust generated per unit area of floor is not high. To capture this dust as it is generated and keep it away from the operators is virtually impossible, and a high standard of general ventilation is relied on to improve conditions. Where this is unacceptable there is no real alternative to mechanization, so all shakeout operations will take place at one point and dust control can be applied. In other words, mechanical handling has to be installed to make a satisfactory solution possible.

Manual Shakeout--
In mechanized foundries, shakeouts loaded by workers using overhead hoists are still used in large numbers. When dealing with flasks of variable size having bars in either half it is difficult to use any other design of shakeout. Once the shakeout operation is confined to one place it is possible to fit it with reasonably efficient dust control.

Many early shakeout tables had downdraft exhaust through the perforated table since this allowed access on all four sides for the operators. Downdraft, however, is not recommended for shakeout for various reasons:

1. Even when shallow flasks [not more than 30 cm (12 in.) high for the assembled mold] are used the air flow required to control dust is very high, 5 m/sec (1000 ft/min) or more over the full grid area.

2. If deeper flasks are being knocked out [over 30 cm (12 in.) total] quite unacceptable exhaust rates would be required for control.

3. The exhaust air flow is drawn through the falling sand under the grid and results in a very high pickup of fines, sufficient in many cases to upset sand control and overload the dust collector.

It is more usual, if less practicable from a flask and casting handling standpoint, to use a sidedraft hood on the longest side of the grid. Given the correct exhaust rate, most dust can be kept out of the operator's breathing zone, but it remains a hot, unpleasant task which can only be improved by further mechanization.

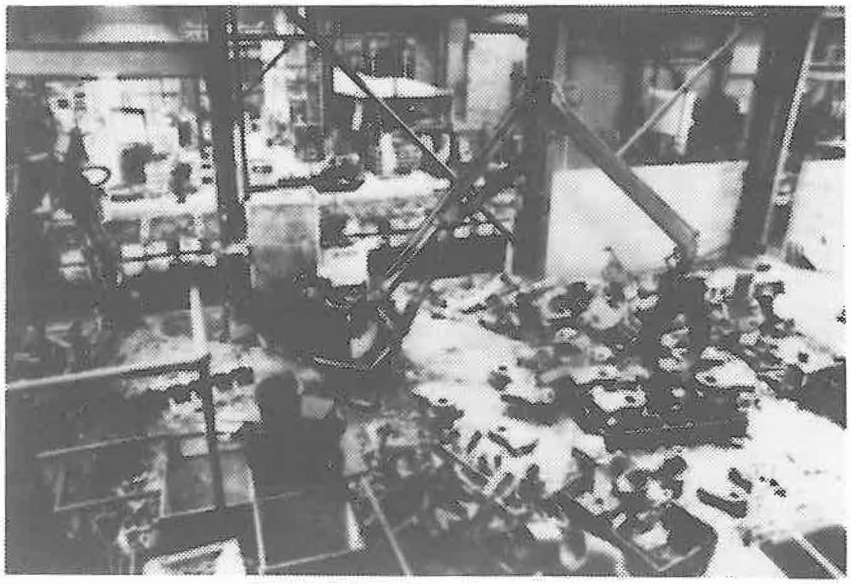

Figure 12. The use of a mechanical manipulator for shakeout.

Mechanical Manipulation Handling--
Automatic handling may be considered as an alternative to manual handling aided by hoists. This method allows full access to the shakeout table since exhaust hoods do not have to be as close-fitting. The operator is housed in a ventilated booth and handles castings and flasks using a powered manipulator. One such system is used in Sweden, and allows the simple system in Figure 12 to be used (6). It does not, however, eliminate the need for dust control. The shakeout needs to be ventilated to prevent dust from reaching other unprotected workers in other parts of the foundry, and to keep this foundry clean.

Automatic Shakeouts--
Vibrating shakeouts can be contained in an enclosure provided that they are made automatic, and this allows dust control to be effective with relatively low exhaust air flows.

No successful automatic shakeout has yet been made which can deal with a variable flask size combined with bars in one or both halves. However, an ever increasing number of mechanized foundries now use standard size barless flasks and, for these, enclosed automatic shakeouts are both economic and improve working conditions by:

1. Removing the operators from a hot, unpleasant job.
2. Allowing efficient dust control to be installed.
3. Providing the possibility of noise control.

Figure 13. shows a typical automatic shakeout layout and Figure 14 illustrates a successful early 1950's mechanized foundry (now superseded) which had an enclosed automatic shakeout.

It is even possible to construct such a system above floor level where floor excavation is not possible. Figure 15 is a photograph of an above-floor level shakeout where the operators simply feed the unit with boxes via a lift.

Flaskless molds such as those produced by DISA machines readily lend themselves to automatic shakeout and a good example is shown in Figure 16. Here the molds at the end of the line enter a rotary drum which is well enclosed and discharges sand and castings separately. Note the heated and insulated exhaust duct to prevent condensation and consequent dust build-up inside the duct.

REFERENCES

1. Bright, J., and Shaw, F. M., The Effect of Moisture on the Amount of Dust Produced by Foundry Sand, BCIRA Journal of Research and Development, 1952, v. 4, December, pp. 426-429.

2. Godding, R. G., and McCormack, W., Hot Sand Cooling in Existing Handling Plant, British Foundryman, 1968, v. 61, March, pp. 95-103.

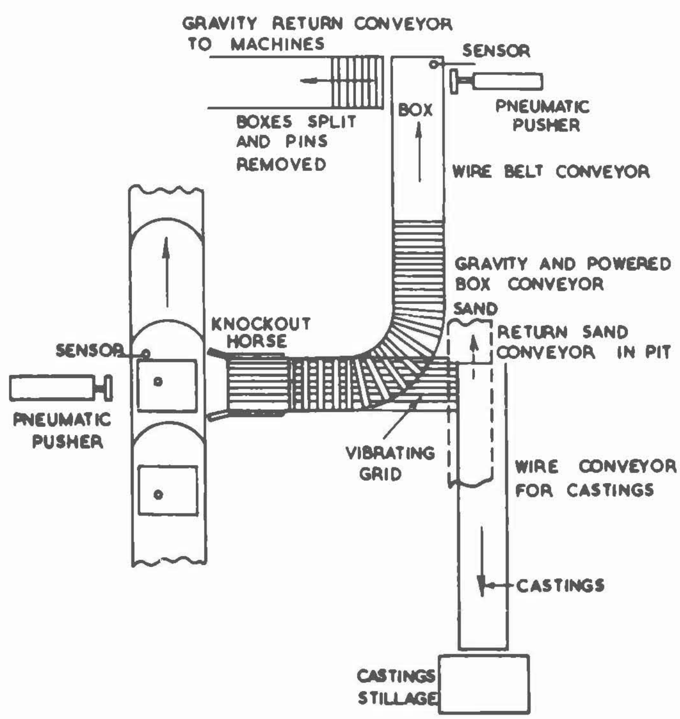

Figure 13. Automatic knockout plant.

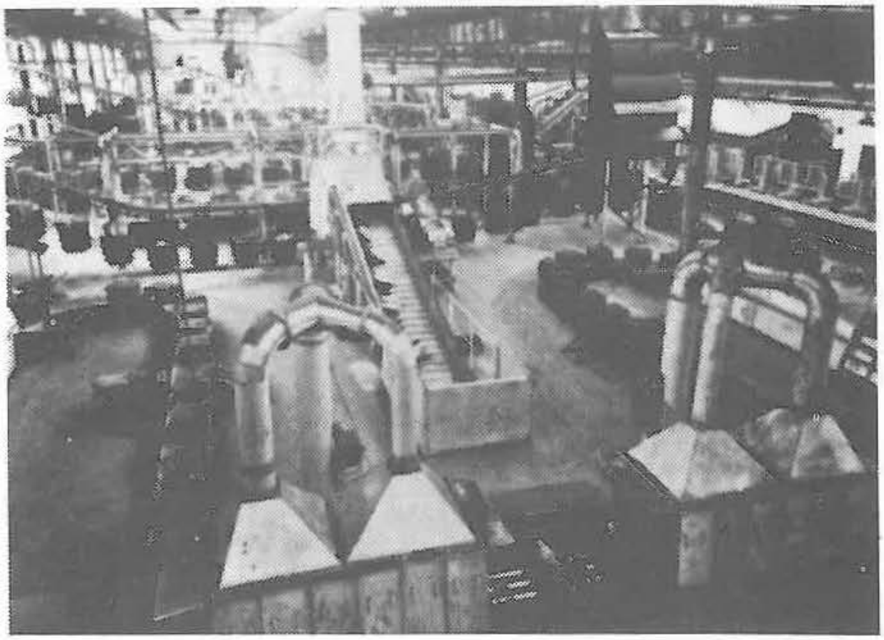

Figure 14. Automatic knockout of the 1950's.

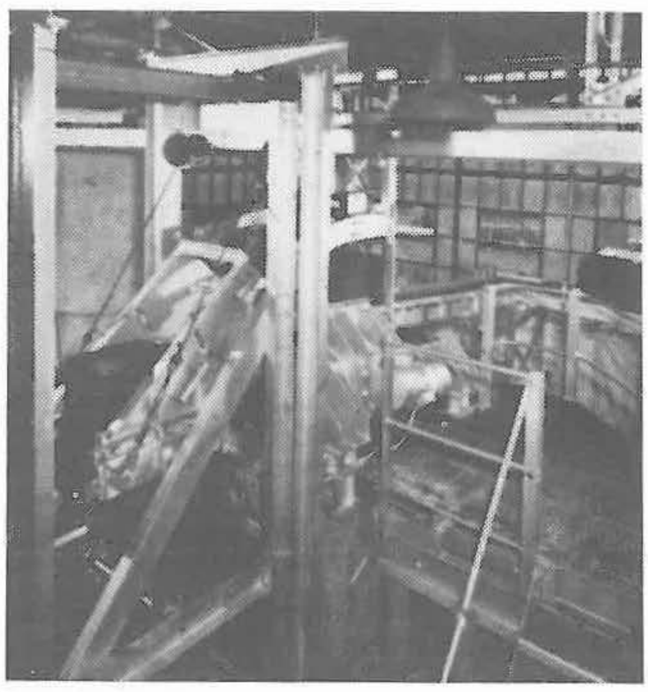

Figure 15. Above ground automatic knockout.

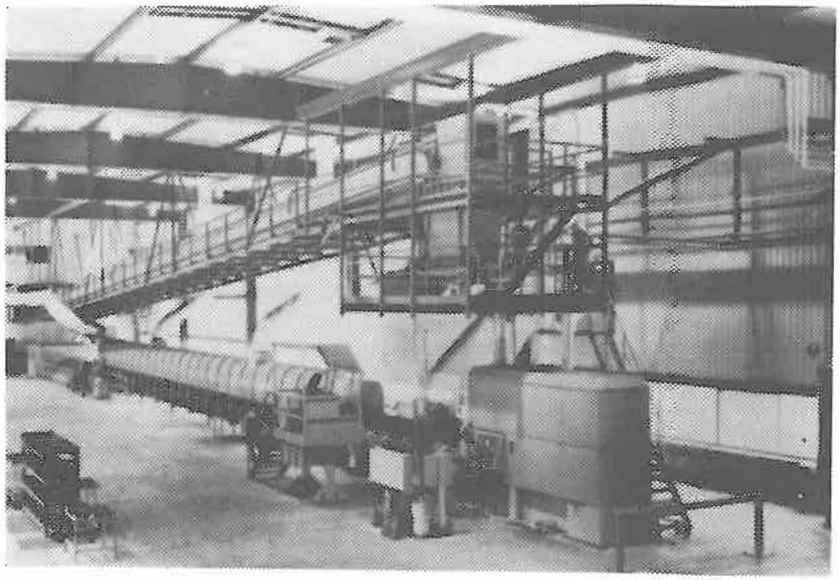

Figure 16. DISA plant using rotary drum knockout.

3. BCIRA, Fast Sand Cooling with Water Evaporation, BCIRA Broadsheet 51, 1972.

4. Pinfield, R. O., Unpublished Work at BCIRA.

5. Drywood, R. C., Unpublished Work at BCIRA.

6. Svensson, I., Manipulators and Industrial Robots in Sand Foundries, 43rd International Foundry Congress, 1976, Bucharest, Paper 19, 12 pp.

QUESTIONS, ANSWERS AND COMMENTARY

Comment (R. Scholz, Rexnord Inc.):

The effectiveness of the Schumacher process in terms of worker exposure to dust has been documented in our NIOSH report on health hazard control technology in the foundry industry. There is also a reprint available of a presentation George Tubich gave at the American Industrial Health Conference in San Francisco in 1972, which includes dust measurements in three foundries employing the Schumacher process.

Response (F. Shaw):

We have a number of Schumacher plants in the United Kingdom, and I'm waiting to see them in operation. Thus far, every time I've tried there have been problems with the systems which have delayed my visit. I don't believe anything unless I've measured it myself. I would appreciate the results of Mr. Tubich.

Comment (J. Calhoun, White Consolidated Industries, Inc.):

In regard to pneumatic conveying of foundry sand, we have two foundries which we have converted to no-bake molding. From the conclusions we've drawn there, there is a great hazard with conveying pneumatically. Whether or not this applies also to green sand shops I can't say.

It seems to me that a system that is relatively high pressured, as a pneumatic system must be, has a problem once a failure or a leak occurs. Leaks can appear anywhere in a bin or a problem may occur with the exhaust device that permits the air and not the sand to be exhausted from the bin or a leak may develop in any of many other places.

We seem to be able to convey sand with less airborne dust by belts than by pneumatic conveying. And we're a little bit soured on pneumatic conveying for that reason.

Response (F. Shaw):

Yes, I think I would agree. If a leak appeared in a pneumatic system, then dust would be discharged. But, then, of course, a leak in the pipework signals the fact that conveying was not being done properly and the system needs more repairs than just plugging the leak.

Normally speaking, the self-cleaning fabric air cleaners for hoppers are not a problem. I'm specifically talking, of course, about clay bonded sand. Furan sand may, in fact, be a better application for pneumatic conveying.

Question (D. Pullen, Pacific Steel Foundry):

McCarver has come out with a low-velocity high-pressure pneumatic transport system. Do you have any experience with those systems?

Answer (F. Shaw):

To my knowledge it isn't any different than the systems we already have in Europe, where generally speaking, they're divided between high pressure, medium pressure, and low pressure. If there is anything different about it I would be interested to know.

NIOSH

Proceedings of the Symposium on Occupational Health Hazard Control Technology in the Foundry and Secondary Non-Ferrous Smelting Industries

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

PROCEEDINGS OF THE SYMPOSIUM ON OCCUPATIONAL HEALTH HAZARD CONTROL TECHNOLOGY IN THE FOUNDRY AND SECONDARY NON-FERROUS SMELTING INDUSTRIES

December 10-12, 1979
Chicago, Illinois

Rexnord Inc.
Environmental Research Center
Milwaukee, Wisconsin 53214

Symposium Coordinators:
Robert C. Scholz
La Donna Leazer

Contract No. 210-79-0048

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
4676 Columbia Parkway
Cincinnati, Ohio 45226

August 1981

DISCLAIMER

NIOSH Project Officer: Dennis O'Brien
Project Manager: Robert C. Scholz

DHHS (NIOSH) Publication No. 81-114