CONCEPTS TO BE EVALUATED
IN THE USE OF CRANES FOR REFUSE HANDLING

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ABSTRACT
The purpose of this paper is to define the concepts and options available in refuse handling cranes in facilities using the crane/pit design. The following topics will be covered:
1. Operator location - in cab attached to crane or in pit remote from crane;
2. Motor control location - on board crane or off-board crane;
3. Electrical communications of remote operated cranes - hardwired or radio control;
4. Crane operation - manual or automated;
5. Refuse handling grapples;
6. Criteria to be considered to maximize on-line time.

INTRODUCTION
The disposal of refuse is fast becoming a subject of major importance in this country. One of the main reasons is the energy crunch. Another is the growing problem of how and where to dispose of the awesome amounts of refuse produced in our homes, businesses and institutions.

For the past decade much of the refuse generated in this country has been either dumped and buried at landfill sites or just simply incinerated. Today, many federal and state laws are putting an end to these disposal practices. Because of similar problems, and especially high energy costs, Europe has developed highly successful resource recovery or waste-to-energy facilities which burn refuse to generate steam.

The burning or incineration of refuse in this country is not new. In fact, many of the successful operations cited in this country are presently using incineration as a method for refuse disposal. The majority of these operations are presently using the crane/pit method of refuse handling.

Today, many of the larger (150 TPD and over) and successful refuse plants in operation in this country are using proven European technology. Most of these refuse plants utilize the crane/pit method, which is also the universal European practice for receiving, storing and feeding the solid waste.

To some new to this field, the crane/pit method of handling refuse may appear incredibly archaic. However, efforts to supplant the crane/pit method with alternate handling equipment have not been very successful. Reasons for this are:
1. Need for adequate storage capacity;
2. Vector control;
3. Fire control;
4. Compaction properties of refuse;
5. Non-homogeneous nature of the refuse; and
6. General housekeeping. High capacity plants must address the crane/pit method as vital to meet production needs. It is important that plant designers are made aware of the latest state of the art in these refuse handling crane concepts.

OPERATOR LOCATION
One of the most important workers in a refuse plant utilizing the crane/pit method is the crane operator. A skilled operator must divert troublesome bulky items to avoid problems in the furnace and mix segregated, highly combustible and noncombustible wastes in the pit so as to avoid excessive or insufficient heat release in the furnace. He must also monitor the flow of refuse into the system and alert the furnace operator of bridging conditions in the charging hoppers.
Many of the cranes presently used for refuse handling in the U.S. are controlled by an operator located in an air-conditioned cab attached to the crane bridge. These cabs are located to provide the operator optimum vision into the storage pit as well as the hoppers (Fig. 1).

Access to the crane mounted operator's cab is generally from a platform mounted in the building at one end of the runway or by a retractable ladder from the cab elevation to the charging floor. As a means of egress under emergency conditions, such as a pit fire, a ladder or stairway is provided from the cab to the crane bridge platform.

The equipment provided in the operator's cab is usually limited due to the size of the cab. The equipment provided consists of a padded seat, master switches, warning device switch, light fixture, convenience outlet, air conditioning and heating controls and optional communications system. The master switches are either the long handle floor mounted type, short handle pedestal mounted type or short handle armchair mounted type.

Because the cab is rigidly attached to the crane bridge, the operator is subject to fatiguing vibrations along with shock and impact forces inherent in the operation of a refuse handling crane. The environmental conditions inside the cab are normally not much better than that outside the cab. To improve these conditions (removal of smoke, dust and odor) would require special filters and air purifiers. Items such as these are available, but get rather expensive, and require periodic maintenance and additional space requirements. The equipment space requirements can be a problem, especially on cranes with very short spans.

Where there is increased concern for the health, productivity and safety of the crane operator, the operator may alternately be located in a stationary pulpit which is in the building remote from the crane. The pulpit can be located either on the front side of the pit over the tipping floor, at the end of the pit, or on the back side of the pit between the furnace hoppers so as to provide a view of the tipping area, the storage pit and furnace hoppers (Fig. 2).

This pulpit may be equipped with adjustable lighting, tiled floor, convenience outlets, wall clock and circulation fan. The pulpit is air-conditioned and heated. Air ducts are provided with replaceable filters to a supply of
fresh makeup air and to obtain a positive pressure within the pulpit.

In larger plants, the pulpit may be large enough for two operator's stations, side by side, located behind a bay window facing the storage pit. In addition to the master switches, and various pushbuttons and pilot lights for the cranes, the pulpit may also be made large enough to contain stoker controls, monitors, fire control devices, weigh indicators, communication system, etc.

**MOTOR CONTROL LOCATION**

The motor controls of a refuse handling crane are the electrical devices which are designed to effectively control the speed/torque characteristics of the drive motors for the hoist and traverse motions of the crane. These controls consist of control panels with contactors, overload relays and circuit breakers, mounted in large enclosures along with resistors and/or reactors, etc.

Today's development and use of solid state devices in the motor controls are contributing factors in helping to provide a continuous and efficient operation of the refuse handling crane. Like any other electrical device, elements such as heat, dust, humidity, vibration, etc. affect the operation and life expectancy of the controls. Therefore, not only is the proper selection of the controls essential to the success or failure of a heavy duty refuse handling crane, but also the location of the controls is equally important.

The motor controls for refuse handling crane are located in either of one of two locations: on-board the crane or off-board the crane.

Motor controls for cab controlled refuse handling crane are generally located on-board the crane (Figs. 3a and 3b). Motor controls located on-board the crane are most often mounted on the crane bridge drive girder platform. For ease and safety during servicing, a minimum of 30 in. is required in front of all control enclosures. On extremely short span cranes, the control is most likely to be mounted on both the driver girder and idler girder platforms, resulting in a very wide crane.

Certain factors, such as poor environmental conditions
FIG. 3A CAB CONTROLLED CRANE WITH MOTOR CONTROLS LOCATED ON-BOARD CRANE

FIG. 3B MOTOR CONTROLS LOCATED ON-BOARD CRANE
(high ambient, humidity, heavy dust, smoke, etc.) present in the pit area of most refuse plants, along with constant vibrations generated by the crane and runway, can be detrimental to the controls, resulting in the need for additional maintenance. Lack of maintenance and/or proper adjustments will mean less efficient operation, more downtime, more expensive repairs and a possible reduction in the life expectancy of the motor controls. In applications where extremely harsh environmental conditions exist, it may be necessary to filter the air in the control enclosures. In situations where there are severe vibration problems due to very poor runway conditions, it may be desirable to shock mount the motor controls.

The motor controls for remote operated refuse handling cranes may be located either on-board the crane or off-board the crane. The preferred location for the controls of remote operated cranes is off-board in a clean and well ventilated control room (Figs. 4a and 4b). Location of the controls off board in a clean environment has certain advantages over that of control location on board the crane. The advantages are as follows:

(a) longer life expectancy due to the absence of vibrations along with shock and impact loads;
(b) less maintenance and less adjustments, resulting in more on-line time operation;
(c) better maintenance due to a clean and odorless environment;
(d) a lighter crane resulting in lower power consumptions and lower building costs;
(e) mechanical maintenance of the crane will be simpler and easier due to fewer space restrictions allowing better access to the mechanical devices such as the bridge drive reducers, line shaft couplings and bearings, etc.

ELECTRICAL COMMUNICATIONS OF REMOTE OPERATED CRANES — HARDWIRED OR RADIO CONTROL

When discussing the different electrical communication systems (runway conductors) available for remote operated cranes, it is necessary to first define the function or purpose of these conditions.

A remote operated crane with motor controls located on-board the crane require conductors to deliver: (a) main power or current to the crane; and (b) master switch control signals from the operator's station which is located remote from the crane to the motor controls located on-board the crane. The main power conductors carry high voltage and usually consist of three conductors (one for each phase of a three phase power supply). The master switch control conductors carry low voltage and consist of between 10 to 15 conductors per motion. A remote operated crane with motor controls located off-board the crane require conductors to deliver (a) current to the individual motors of each motion located on the crane; and (b) control of other devices, such as limit switches located on the crane. The current carrying conductors to the individual motors are high voltage conductors and usually consist of between 6 to 10 conductors per motion. The control conductors are low voltage and consist of 2 to 6 conductors per control device. Remote operated cranes with motor controls located on-board the crane can utilize several types and/or combinations of electrical communication systems.

The main power conductors can consist of either a rigid type enclosed conductor system or a festooned conductor system using portable insulated multi-conductor flexible cables supported by an adequate number of four wheel trolleys operating on the bottom of an I-beam track. Main power conductors of the rigid type may be more economical than the festooned conductor system if multiple cranes are on the same runway since the cranes can share the same rigid conductors. Multiple cranes on the same runway using a festoon conductor system are each required to have their own independent festoon system. The only item shared between cranes using a festoon system is the structural I-beam track and supports. The festoon conductor system is basically a low maintenance item and is well adapted to dust environments such as this. The rigid type conductor system requires sliding shoe type collectors which do require some maintenance and periodic replacement of the collector shoes.

The master switch control signals can consist of either a hardwired festooned conductor system or a wireless remote radio control system. Rigid type conductors are not used for master switch control signals mainly due to the large number of conductors required and certain types of controls cannot function properly with a sliding type of collector/conductor arrangement. As mentioned before, the festooned conductor system is basically a low maintenance item and is well adapted to this environment. However, there is a certain amount of interconnecting building wiring required by the purchaser from the master switches to this festoon system. The use of a wireless remote radio control can eliminate the festoon control conductors plus the interconnecting building wiring. The radio control itself is a sophisticated piece of equipment and may require a specialized service technician in the event of an operational and/or service problem. A backup operator's station (pendant pushbutton station) located on the crane(s) is recommended to aid in the isolation of an operational problem if a wireless radio control system is used.
FIG. 4A REMOTE OPERATED CRANE WITH MOTOR CONTROLS LOCATED OFF-BOARD THE CRANE

FIG. 4B MOTOR CONTROLS LOCATED OFF-BOARD CRANE
Fig. 5A Remote Operated Crane with Hardwire Electrical Communication System

Fig. 5B Remote Operated Crane with Wireless Remote Radio Control System
The main power conductors and master switch control signal or conductors can be mixed depending on the application, economics or customer preference. For example, if rigid type conductors are being used for the main power to the crane(s), the master control signals could be of the hardwire festooned conductor type or the wireless radio control system. If a hardwire festooned conductor system is being used for the main power, the master switch control signals could also be transmitted by the hardwire festoon system or the wireless remote radio control system.

Because of the extensive number of conductors required for remote operated cranes with controls located off-board the crane, it is most practical and recommended that the hardwire festooned system be used. However, with motor controls located on-board the crane, radio control is a viable alternative (Figs. 5a and 5b).

CRANE OPERATION – MANUAL OR AUTOMATED

Can new developments in automation be applied to refuse handling cranes? One form or another of automation is presently being used in the making and rolling of steel, manufacturing of automobiles and many other material handling applications. The state of the art is proven and benefits are many. Automation of equipment should be considered if the following benefits can be obtained:

(a) increasing of productivity;
(b) increasing on-line time and life expectancy of the equipment.

In refuse facilities using the crane/pit system for refuse handling, the overhead traveling crane is required to perform the following functions:

(a) prepare room in the pit adjacent to the tipping area for incoming refuse;
(b) mix segregated and highly combustible wastes with regular, or low Btu wastes to insure a reasonable consistency and therefore avoid excessive heat release in the furnace;
(c) retrieve refuse from the pit and discharge into the hoppers;
(d) divert and remove troublesome and bulky items from the pit or hoppers.

In performing all of the required functions of the crane, there exist both predictable repetitive cycles and unpredictable non-repetitive operations. Some of these unpredictable operations are caused by:

(a) various classifications and density of refuse;
(b) different locations where the refuse is discharged into the pit;
(c) variations in the amount and time in which the refuse enters the pit;
(d) varying angles of repose of the refuse in the pit;
(e) interference with trucks.

Because of these unpredictable operations, it requires visual acuity and good judgment on the part of the crane operator in order to perform the above functions in an efficient and successful manner.

With today’s technology, it is both possible and practical to automate refuse handling cranes, however, the automation is limited to those functions which have defined cycles and repeatability. In the case of the crane/pit system, the function(s) which have defined cycles and repeatability are the hopper charging cycles.

In the hopper charging cycle, those crane motions which can be automated include:
- Hoisting of the loaded grapple
- Trolley and bridge movement of the loaded grapple to a selected hopper
- Lowering of the loaded grapple into the hopper
- Discharging the refuse into the hopper
- Hoisting of the empty grapple out of the hopper
- Trolley and/or bridge movement of the empty grapple back to a selected location over the pit

Again, because of the unpredictables of the refuse in the pit, including varying elevations and angles of repose, troublesome and bulky items and the possibility of trucks discharging refuse into the pit, the crane operator should control the final bridge and trolley positioning, including the lowering of the grapple into the refuse pile and closing of the grapple, thus completing the cycle.

With the assistance of automation, productivity is increased due to the reduction in operator fatigue. On-line time and the life expectancy of the equipment may be increased due to the reduction in operation abuse. With higher levels of administrative control in the collection and dumping of raw refuse and in those refuse plants handling shredded refuse, it may be possible to reduce the number of unpredictables and variables, allowing automation to be utilized to a much greater extent.

REFUSE HANDLING GRAPPLES

Unlike other homogeneous materials, refuse is one of the few raw materials that has the characteristics of a continually varying density. These characteristics are dependent upon place of origin, method of collection, depth of storage, length of storage or various combinations of these factors. The most practical method of handling this type of raw material in a facility using the crane/pit design is by grabs or grapples connected to the wire rope system of the electric overhead traveling cranes.

The types of grabs or grapples generally used for refuse handling by electric overhead traveling cranes can be divided into groups determined by the method of actuation.
employed and the basic shape of the device. The opening and closing of these grapples is actuated either by a wire rope system or by an electric-hydraulic system. The principal shapes are either the two jaw clamshell type or the multi-shell orange peel type. Both shapes are available in either the rope actuated type or electric-hydraulic actuated type.

In the U.S.A., the most popular type of grapple presently being used for refuse handling applications is the long tine clamshell grapple. This grapple consists of two cut away jaws with long pitchfork type tines fastened to the bottom lip of the jaws. Because of its better digging characteristics, the long tine clamshell grapple has replaced the earlier clamshell incinerator buckets. Unlike the long tine clamshell grapples, the earlier incinerator buckets consisted of two enclosed jaws fitted with short teeth. These clamshell incinerator buckets are now rarely being used. The majority of the clamshell grapples being used in the U.S.A. are of the three rope suspension (two holding ropes and one closing rope) or four rope suspension type (two holding ropes and two closing ropes). They are suspended from the overhead traveling crane having both a holding hoist and a closing hoist. There are some refuse handling clamshell grapple applications in the U.S.A. which are electric-hydraulic actuated. These grapples are suspended from an overhead traveling crane using only a holding hoist. In most typical refuse handling applications utilizing the long tine clamshell grapple (rope actuated or electric-hydraulic), the grapple is suspended such that the opening direction of the grapple is usually parallel with the long axis of the storage pit.

In Europe, the most popular grapple used for refuse handling is the orange peel grapple. Just recently, the European design orange peel grapple has been introduced in the U.S.A. for refuse handling service. The orange peel grapples of either system of actuation feel the average filling factor of the orange peel grapple is approximately 15 to 20% higher than the clamshell grapple.

The electric-hydraulic grapples, due to their sophistication, are more expensive than the simpler rope operated grapples. The multi-tine orange peel grapples, even though they are lighter in weight, may be more expensive than the equivalent sized long tine clamshell grapples. However, the crane capacity for a given payload of refuse varies considerably depending on the grapple chosen. Rope operated grapples require a crane system with four separate drive motions. Electric-hydraulic operated grapples can be used on cranes with smaller capacity ratings than their counterparts, the heavy-weight long tine clamshell grapples. For capital cost comparison, the cost of an average four motion (bridge, trolley, hold and close motions) crane system without the cost of the rope actuated grapple is approximately 10 to 15% higher than a comparable three motion (bridge, trolley and hoist motions) crane system without its electric-hydraulic actuated grapple. However, when the cost of the grapples is included with each of the respective crane systems, the cost advantage of the three motion crane is cancelled out.

The rope life of rope actuated grapples is considerably less than that of the electric-hydraulic grapple, specifically the closing ropes. The average life expectancy of rope actuated grapples will vary depending on the type of wire rope being used, the grapple design (sheave diameters, head guide roller assemblies, etc.), and most important, the operation of the crane. Rope life ranges from three to six months on the holding lines, and one to three months on the closing lines. The rope life for an electric-hydraulic operated grapple is similar to that of the holding lines of a rope operated grapple. Therefore, determination in selecting either of the two types of grapples must include evaluating the difference of maintaining the more sophisticated electric-hydraulic grapple versus the necessity of more changing out of the closing line of the rope actuated grapple. The evaluation must also consider whether or not it is desired to carry a space grapple in inventory.

CRITERIA TO BE CONSIDERED TO MAXIMIZE ON-LINE TIME

In a refuse facility using the crane/pit system, the crane and its associated material handling equipment are vital links for a profitable and successful operation. The refuse
handling crane and its associated equipment must be designed to perform 24 hr/day, 365 days per year, year after year with a minimum amount of downtime. Crane reliability is extremely important in these facilities; therefore every effort must be made to provide maximum reliability in this material handling system. Because of the severe duty cycle the crane must perform, the design criteria for this type of crane far exceed that of the customary industrial crane. Some of the extraordinary details to be assessed are increased bearing life, increased gearing durability, motor horsepower sizing for higher acceleration, greater fatigue life in structural design, durable control design and motor and brake thermal reserve.

Reliability is achieved not only by specifying and obtaining equipment sized and designed specifically for this service, but also by taking into consideration other factors such as proper operator training, proper maintenance training and an effective preventative maintenance program. Regardless of how rugged a piece of equipment is designed and manufactured, a poorly trained operator can cause equipment failures resulting not only in downtime but also in unnecessary and expensive repairs and possible reduction in the life of the equipment. Not everyone is capable of operating a refuse handling crane. The crane operator should be well coordinated with good motor skills, timing and aptitude. Training an individual to become a crane operator should be done in his or her own plant environment. In addition to training the operators to operate the cranes, they should be taught about the effects of:

- Collisions (other cranes, end stops, etc.)
- Shock loads
- Traction loses
- Operation abuse

Since many of today's refuse plants are becoming or have become waste-to-energy/resource recovery facilities with the emphasis on the output of energy, the crane operators of today should have a higher degree of skills than the crane operators in the former conventional incinerator plants.

A properly trained maintenance person is just as important as a good crane operator in making the material handling system a successful operation. Because of the high degree of technology and sophistication going into both the electrical and mechanical components being used in today's refuse cranes and associated material handling equipment, specialized maintenance training is required. Manufacturers of this sophisticated equipment have training schools offering courses in the specialized maintenance of this equipment. It is recommended that qualified maintenance personnel attend these courses in order to be provided with the knowledge and skills necessary to keep today's refuse handling crane operating and operating efficiently.

An effective preventive maintenance program is necessary to provide safe and continuous operation of the crane handling system. The refuse handling crane is designed for a useful life of approximately 20 years. This is equivalent to 60 to 100 years of service for a normal industrial crane providing hook type service. Insuring that the crane does provide these years of useful service requires that the crane not only be properly operated, but also properly maintained. Maintenance of the crane and its associated material handling equipment should be done on regular intervals and not only when something has failed. A properly instituted preventive maintenance program reduces overall maintenance costs and prevents serious shutdowns by the forewarning of potential major problems. Minor adjustment, cleaning and parts replacement not only maintain the high efficiency of the crane operation, but also eliminate minor shutdowns and nuisance complaints from operators. A preventive maintenance program includes: (a) periodic inspections of both electrical and mechanical components; and (b) determining that corrective measures are required by checking a report filled out at the time of the inspection. Periodic review of old inspection reports can be a useful tool for predicting the service life of crane components. This will foretell the need for adjustment, repair or replacement of components. The ordering the replacement of parts can be planned in advance, thus minimizing downtime and expense involved.

CONCLUSION

The refuse handling crane is a vital link in the total operation of a refuse facility using the pit/crane system. This paper has presented some of the more important considerations with respect to both the selection of the crane equipment and the alternative concepts available. In evaluating these different concepts, it is necessary to also recognize the importance of proficient operators and maintenance personnel in establishing a more successful and efficient refuse facility.