DESIGN OF AN INCINERATOR FOR THE NUT ISLAND SEWAGE TREATMENT PLANT

By Chester J. Ginder,* Member

An incinerator designed to burn sewage wastes at the Nut Island Sewage Treatment Works of the Metropolitan District Commission is being installed at the present time in an existing building at the site in Quincy, Mass.

The work involved consists of furnishing and installing, complete in full operating condition, one 36-ton per day capacity, multiple hearth, vertical type incinerator with all necessary equipment and connections for incinerating sewage screenings, grit and digester tank scum.

The incinerator is being installed in the Grit Tower at the plant which did house a large grit storage bin fed by bucket elevators from two grit washing machines. Part of the work includes the removal of the grit washer, the bucket elevators, the storage bin and all of the platforms and access stairways in the grit tower. Two mechanically cleaned screens originally installed which had 1¼″ openings are being replaced with screens having ⅞″ openings. Screenings and grit will be transported to bins at the incinerator by means of ejectors. This method required extensions to the compressed air system and the installation of additional air receivers and piping. Piping for transporting scum about 300 feet from the digester tanks to the incinerator had to be installed and also piping for the hydraulic ash disposal system between the ash hopper and an effluent channel.

The installation contract includes 15 items one of which pertains to the burner, appurtenances and controls. The furnishing and installation is the direct responsibility of the general contractor, and although this item is being furnished by Nichols Engineering and Research Corporation, they are not sub-bidders in the usual sense. Other items include such work as removal of concrete floors, cutting and patching masonry, alterations to the grit conveyor, furnishing and installing a vibrating screen to dewater digester scum, replacing

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screens as mentioned, electrical work, compressed air system and painting. The major item of the contract is that of the incinerator and appurtenances which include small collection hoppers, mechanical feeders, a fly ash arrester system, all adjacent to the burner, and all necessary instrumentation and controls.

Types of Incinerators

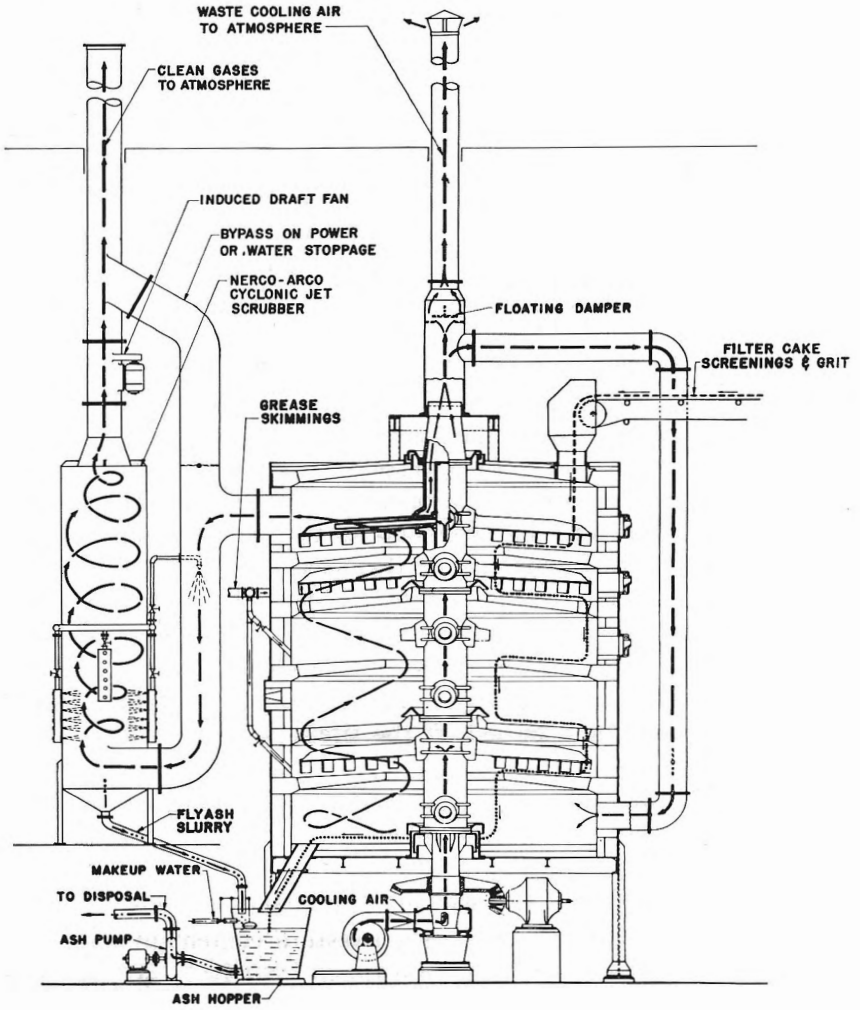
Two general types of incinerators were considered for Nut Island. The horizontal continuous flow type having a moving or oscillating grate and the multiple hearth vertical type. The horizontal continuous flow type of incinerator had had wide usage for burning domestic rubbish and garbage but in few if any cases, has this type of furnace been developed for burning sewage plant screenings and grit. In considering this type of incinerator it was evident that a horizontal type of installation would not be readily adaptable to the space available in the Grit Tower at Nut Island, which is over 4 stories high but has only about 23 × 27 feet of area available for use.

The multiple-hearth vertical type of incinerator could be installed in the space available and in addition, this type which was designed and developed by the Nichols Engineering and Research Corporation of New York primarily for burning or drying sludge, has been in use in no less than fifty sewage treatment plants, some of which have been operating for 25 years or more. Screenings and grit are burned successfully at some plants such as at Milwaukee, where a 48 ton burner was installed in 1952 and a second 48 ton burner installed in 1959.

The Multiple-hearth Type of Incinerator

The multiple-hearth type of incinerator consists of a circular steel shell surrounding a number of solid refractory hearths, generally from 4 to 8, one above the other, and a central rotating shaft to which rabble arms are attached. The hearths are alternately infeed or outfeed hearths so that materials fed at the top will be plowed across the hearth by the rabble arms and drop to the hearth below through ports, either at the center or around the periphery, as the case may be. The central shaft and the rabble arms are hollow and are cooled by air supplied by a blower discharging air into a housing at the bottom of the shaft. Ashes are dumped from the bottom hearth into an ash hopper which in this installation will be mixed with effluent water and pumped to an effluent channel. At Nut Island the flue gases will pass

through a cylindrical fly ash arrester in which water sprays will be introduced, and by means of an induced draft fan discharged through a stub flue stack.



NICHOLS HERRESHOFF SLUDGE FURNACE BURNING FLOW DIAGRAM

The Nut Island Sewage Treatment Works

The Nut Island Plant was designed to serve some 860,000 people in the Boston Metropolitan Sewerage District. The design rate was set at 112 mgd and a design maximum of 300 mgd. It provides primary treatment for wastes from the Southern High Level Sewer which serves areas west and south of Boston which are in the Sewerage District. The plant includes screens, comminutors, grit channels, pumps, aeration tanks, sedimentation tanks, digestion tanks, gas collection facilities, gas storage sphere, dual fuel engines, air compressors, generators and waste gas burners. Provision for pre- and postchlorination are included. The plant had been in operation for seven years at the time the design of the incinerator was made and a considerable amount of operating data was available.

Determination of Design Quantities

One problem which has persisted at the Nut Island Plant is the formation of an excessive amount of scum in the digestion tanks. Although certain variations in operation have had definite effects on the amount of scum formed, the operation procedures followed have not reduced the amount that accumulates to a satisfactory minimum. The practice followed to get rid of this scum has been to blow it off to sea every three or four months through the sludge and effluent lines, an expedient not considered as a satisfactory or acceptable solution.

One alternate to that has been the decision to burn the scum along with the screenings and grit. Up to now the screenings and grit have been removed and buried off the site.

The records indicate that the scum accumulation has averaged about 250,000 cubic feet per year; that it has a moisture content of 95% and weighs 50 pounds per cubic foot.

The records also indicate that 12 to 40 cubic feet of raw screenings have been collected per day at Nut Island, weighing about 62 pounds per cubic foot and having a moisture content of 75%. The grit yield has varied widely also, in a range from 10 to 100 cubic feet per day with a moisture content of about 40%, and weighing 110 pounds per cubic foot. These yields of screenings and grit, when related to the flows through the plant, seemed to show a lower yield per million gallons of sewage than has been the usual experience in similar treatment plants.

It appears that various treatment plants seem to have certain characteristics not common to plants in general and a relatively low yield of screenings and grit per million gallons of flow has shown up in the records at Nut Island. Some explanation for this situation may come partly from the fact that the High Level Sewer is an old facility and infiltration is high and partly from the fact that at pumping stations upstream from Nut Island the sewage is screened.

A review of the experience at numerous treatment plants both large and small, throughout the United States, with screening and grit facilities similar to those proposed for Nut Island shows that with respect to screenings and grit the average quantities removed range in amounts as follows:

	Yield, cubic feet per m.g.		
Material	Low	Average	High
Screenings	0.5	1.0 to 2.0	2.3 to 4
Grit	1.0	1.8 to 2.2	2.8 to 5 or 6

With regard to the amount of scum to be provided for, no comparisons with the experiences at other plants were studied, for as far as I know it is an unusual, if not unique, feature to include scum from the digestion tanks as part of the wastes to be incinerated.

It was decided that improvements would be made in the screening and grit removal facilities and that when these improvements were completed a larger yield of screenings would result and also the removal of grit would be more satisfactorily accomplished.

Throughout the sewerage system screenings and grit are or will be collected at several locations in addition to that of the Nut Island Plant, namely, at the Deer Island Treatment Plant; at the Chelsea Headworks which is at the upstream shaft of a tunnel to Deer Island; at future headhouses at Ward Street and at Columbus Park, which will be at shafts on a second tunnel to Deer Island. Also small amounts are collected at three existing upstream pumping stations on the Southern High Level sewer that terminates at Nut Island. It is proposed to build an incinerator at Deer Island to serve that plant which will be large enough to burn screenings and grit trucked over from the Chelsea Headworks, and it is quite likely that a second incinerator will be built at Nut Island to take care of materials from

other locations in the system south of Boston when the combined quantities to be burned exceed the capacity of the incinerator being built. This solution becomes necessary due to lack of space in the building which limits the size furnace that can be accommodated at Nut Island where the incinerator is being installed.

Changes in the sewerage system being made indicate that the 1985 flows at Nut Island will not be increased much over the present day flows since diversions from the Southern High System to Deer Island will be made. The estimated flows and yields in 1985 for the headhouses, as well as for Nut Island Plant, were determined as part of the design problem and these quantities are listed in the following tabulation:

Location	Flow, MGD Min.	Av.	1985 Max.	Service
Nut Island	78	124	350	Terminus of So. High Level Sewer
Ward Street Headworks	58	113	256	On tunnel to Deer Island
Columbus Park Headworks	30	66	182	On tunnel to Deer Island

The estimated yield of materials in 1985 at the three principle locations was determined to be:

Location	Cubic feet per m.g.		
	Screenings	Grit	Scum
Nut Island	1.0	1.0	5.5
Ward Street Headworks	1.5	2.0	—
Columbus Park Headworks	1.5	2.0	—

In considering the methods of handling the scum it was apparent that the high moisture content of 95% was a definite disadvantage, and that to effect a reduction in moisture would be very desirable both from the standpoint of incinerator loading and the saving in heat which would otherwise be needed to drive off this moisture. Experiments showed that a reduction in the moisture content of the scum from 95% to 89% could be accomplished by holding the scum in a detention tank for about four hours, and this would result in a volume reduction of 50% in the amount of scum to be burned. The experi-

ments also showed that to increase the detention time beyond a four-hour period would mean very little further reduction in moisture.

Experiments were conducted to determine if a mechanical means of dewatering the scum would be practical and it was found that a vibrating type of screen could be depended upon to reduce the moisture to 80% or less. The design figures used were on this basis of moisture reduction to 80% and the installation of a vibrating screen to effect this reduction was included in the incinerator contract. The scum loading for the incinerator design then became only 28% of the scum volume as generated, a reduction from 250,000 cubic feet per year at 60 lbs. to 70,000 cubic feet at 53.8 pounds per cubic foot.

From the estimated 1985 average flows and the estimated yield of materials the total quantities which may be removed at Nut Island and at the Headworks is computed to be:

	Nut Island only	Ward St. only	Columbus Park only	Combined total
Coarse screenings yield (lbs. per day)	7700	10,500	6120	24,320
Grit—unwashed yield (lbs. per day)	13,600	24,900	14,500	53,000
Digester scum, 80% moisture yield (lbs. per day)	10,300	—	—	10,300
Total (lbs. per day)	31,600	35,400	20,620	87,620
Tons per day	15.8	17.7	10.3	43.8

Basis of Design

The quantity figures listed are based on average flow conditions and from these figures it was concluded that an incinerator at Nut Island large enough to take care of screenings and grit from the Headhouses even for everage flows would be too large to be accommodated in the space available at Nut Island. It was decided therefore to give primary consideration to the requirements for Nut Island and if the operating schedules later permit, materials from the Quincy, Braintree-Weymouth and Houghs Neck pumping stations yielding relatively small quantities may also be trucked to Nut Island for burning.

The operating schedule adopted as part of the plant operation is a major matter to be considered in establishing the size of the incinerator to be selected. Many installations are operated on a 24 hour a day basis, year in and year out, and under those conditions have been run continuously for years.

If the operating schedule is to be for less than 7 days a week and for less than 24 hours per day the size required must be increased accordingly. Also, the storage of materials during the time the burner is shut down becomes a problem. To take care of the quantities listed on part time operation would require burner capacities even for average conditions during a wet month such as March, as follows:

7 days per week at 24 hours	24 tons
6 days per week at 24 hours	28 tons
5 days per week at 24 hours	33 tons
7 days per week at 16 hours	36 tons
6 days per week at 18 hours	36 tons

For operations 18 hours a day on a six day week storage facilities for 15 or more tons of screenings and grit may be needed. Scum need only be burned at times of low flow since it can be left in the digestion tanks until burning is convenient. This has the effect of providing increased capacity during peak flow conditions for burning screenings and grit.

On the basis that the requirements for the Nut Island Plant would be of primary importance, and from the amount of materials to be burned, the schedule of operation, the storage facilities and the space available at Nut Island, it was decided that an incinerator having a nominal burning capacity of 36 tons per 24 hours of wet feed would be specified.

Wide variations from the yearly average flows occur at most any season of the year such as 120% in March, 118% in November, 83% in June and 76% in July. During periods of high flow it is expected the facilities will be overtaxed.

The furnace specified is the multiple-hearth type of incinerator in which the materials pass through the burner from top to bottom. The requirements are that the furnace shall be capable of burning screenings, grit and digester scum in the following quantities:

Materials	Pounds per hour				
	Water	Combustibles	Ash	Total	Percent of total
Coarse screenings	1024	307	34	1365	46
Unwashed grit	360	162	378	900	30
Digester scum	588	103	44	735	24
	1972	572	456	3000	100

In addition, the furnace shall be capable of burning the materials as follows:

(1) 1800 pounds per hour of wet unwashed grit

(2) 1500 pounds per hour of wet coarse screenings

(3) 1800 pounds per hour of wet unwashed grit and wet coarse screenings in any proportion, but with the quantity of either material not exceeding those in (1) or (2).

(4) 1000 pounds per hour of wet digester scum with (1), (2) or (3).

It was determined and specified that the design of the furnace and its auxiliaries should be based on destroying materials having the following characteristics:

	Average	Range
Coarse Screenings		
Moisture content	75%	65%–85%
Dry solids content	25%	15%–35%
Combustible solids content (dry basis)	90%	85%–95%
Ash content (dry basis)	10%	5%–15%
Heat value per pound of combustible solids	8300 BTU	7000 BTU–10,000 BTU
Unwashed Grit		
Moisture content	40%	30%–60%
Dry solids content	60%	40%–70%
Combustible solids content (dry basis)	30%	20%–50%
Ash content (dry basis)	70%	50%–80%
Heat value per pound of combustible solids	12,000 BTU	10,000 BTU–15,000 BTU

Digester Scum		
Moisture content	80%	75%–85%
Dry solids content	20%	15%–25%
Combustible solids content (dry basis)	70%	60%–90%
Ash content (dry basis)	30%	10%–40%
Heat value per pound of combustible solids	17,000 BTU	15,000 BTU–19,000 BTU

Figures pertaining to the heat balance indicated an excess of heat available and that once started the burning process will be self sustaining.

Methane gas generated in the digesters is compressed and stored in a 90,000 cubic foot capacity Hortonsphere at 30 psi. This gas is the principal source of fuel for all plant power and heating purposes. It will be used in burners for starting up the incinerator and maintaining suitable temperatures in the hearths during shut-down periods. Gas production is rather high at the plant, amounting to 1,300,000 cubic feet on a recent day, a figure of about 1.5 cubic feet per capita. The gas system includes six waste gas burners having a capacity of 6000 cf per hour and one or more of these burners is in continuous service. The gas has an average heat value of 625 BTU.

Further general requirements called for furnishing auxiliary equipment, including a vibrating screen to dewater the scum, a fly ash arrester system and a hydraulic type ash disposal system. The entire incinerator and much of the equipment is being installed in the tower at the Plant, a space restriction which seemed to preclude the use of any burner except the multiple hearth vertical type.

Incinerator Details

The multiple hearth incinerator consists of six circular hearths, one above the other, constructed of firebrick shapes, forming domed arches, supported by the side walls. Side walls are constructed of firebrick and insulation encased in a steel shell. The bottom hearth is a flat disc, paved with firebrick and insulation supported by steel members. Gas and oil burners are provided.

Mechanical stoking is provided by a motor-driven revolving central shaft, to which are attached radial arms with rabble arms or plows to take material deposited on the hearths either towards an opening next to the central shaft, or to openings around the periphery

of the hearth, alternately, as it descends from each hearth to the next lower hearth.

The furnace is so constructed and the hearths so arranged to provide three rather distinct zones within the furnace:

(1) A Drying Zone—where a major portion of the free moisture in the material is evaporated.

(2) A Burning Zone—where the material to be destroyed is burned, and

(3) A Cooling Zone—which will serve to cool the ash prior to the discharge of the ash to the ash quenching facility, or ash hopper.

These areas or zones are proportioned so that these functions will be performed within the furnace regardless of a considerable variation in the moisture and volatile characteristic of the material and the quantity being fed to the furnace.

The furnace is designed and arranged so that the hot gases from the burning zone or area will be directed over the wet, cold materials entering the drying zone of the furnace and so proportioned that the combustion gases will give up a considerable portion of their heat to the materials, with a drop in temperature of the gases from about 1600°F to about 750°F, or lower, without raising the temperature of the materials to be burned to more than 160°F in that zone. The objective is to insure that no significant quantity of volatile matter will be driven off in the drying zone and no obnoxious odors will be produced in this zone or area of the furnace.

A recirculating duct outside the furnace leads from the air exhaust vent at the top of the central shaft to the combustion space on the bottom hearth.

The central shaft is motor driven through means permitting adjustment of speeds from one revolution in two minutes to about three revolutions in one minute, as required.

Furnace—12′ 10″ dia, six hearths. (Weight about 80 tons.)

Shell—½″ steel.
Doors—2 on each hearth, cast iron, observation openings.
Central shaft—outer shaft of heat resisting cast iron.
Rabble arms—4 each on top two hearths and bottom hearth
2 each on other hearths
can be removed through the work doors without entering furnace.

Burners—separate burners for 625 BTU methane gas and for No. 2 fuel oil.
Material feeders—screw conveyors from collection bins.
Ash disposal—storage hoppers with connections for fly ash slurry and effluent make-up water, pump and controls. Capacity of system, 750 pounds of ashes per hour.

The fly ash arrester as specified calls for a water spray type with necessary flue connections to the furnace and to the gas stack. Fly ash slurry formed from the fly ash trapped by effluent water sprays will be sluiced to the ash removal hopper.

With regard to the material feeders, a considerable amount of study went into the problem of feeding unground screenings into the burner although there is reason to feel that better operation would result if these screenings were ground. This situation came first from the fact that a suitable grinder did not seem to be available since grinders which we have used at various locations have not proven reliable enough or suitable for use in this installation. However, rather recently a grinder has been built by the Ray-Mo Manufacturing Company of Verdon, Nebraska, known as their "Master Crusher" which may be suitable for this service since at Milwaukee for a similar service this type of equipment is reported to be doing a satisfactory job. Secondly, at Nut Island, all electric power is generated in the plant and the connected electrical load has been increased from time to time to the point where no further significant increase can be tolerated. No transformer capacity is available for additional equipment either, so the idea of installing a grinder for the coarse screenings due to the very great expense which would have been involved, was finally given up. We are not convinced that a grinder is absolutely essential but do feel that if other conditions permitted, it would be best to grind the screenings.

Presumably if and when an incinerator is designed for Deer Island the use of grinders will be included.

Auxiliary Equipment

The auxiliary equipment required with the burner include those facilities located adjacent to the burner such as collection bins, feeding devices, blowers, dampers, pumps and fans, all of which are furnished by the burner manufacturer. Other facilities such as ejectors

and piping to transport screenings and grit, the piping required for transporting scum, gas and effluent water, and also the scum dewatering device, are furnished by the contractor under other items of the contract. The dewatering device consists of a horizontal vibrating screen approximately 2 feet wide by 4 feet long, mounted in a trough on flexible leaf springs and capable of being vibrated at high speed by an electromagnet. The device will be capable of dewatering scum from a moisture content of approximately 95% to approximately 80% at a rate of 1300 cubic feet of scum per hour. Drains from this device run to the ineffluent channel.

Instrumentation and Controls

Included in the item for furnishing and installing the incinerator are complete instrumentation and control systems for the operation of the incinerator and appurtenances and for the auxiliary component mechanisms such as material feeding equipment and ash removal systems. A control panel is being furnished with all accessories needed for registering and recording temperatures in hearths, flues, and at all critical locations; draft gauges, stop-start push buttons, running lights for all motors; meters, clock, warning lights, alarms, pyrometer and thermocouples and any other instruments or controls needed for proper operation of the installation. Bin indicator lights, ejector indicator lights and flow indicator lights for the scum line will provide information of conditions in the feeding system. The panel is located on the second level in the grit tower.

The contractor guaranteed with his bid that the incinerator will meet the performance requirements. These include the satisfactory burning of 36 tons per day of a mixture of grit screenings and digester tank scum with the further stipulation that the amount of putrescible matter in the ash will be zero; the amount of combustile matter in the ash will be less than 5 per cent; there will be no odor; the degree of darkness or density of the smoke emitted will not exceed the density indicated by Ringleman's Chart No. 2 for a period of more than six minutes in any one hour. Also that dust or fly ash emission will not exceed 0.85 pounds per 1000 pounds of stack gases, adjusted to 50 per cent excess air.

The Massachusetts Department of Public Health is concerned with all phases of our sewerage program as that department has to approve the general features of design.

The trucking of screenings and grit to a remote area for burying has not been considered a satisfactory method of disposal and the proposal of incineration was approved in principle.

Certain details of the design were worked out with the Department such as the disposal of the ash into the effluent channel and the inclusion of a fly ash removal system. It is felt that the ash will be carried through to the outfall and that it may possibly cause some scouring to growth which is found in the conduit.

The location of the Nut Island Plant is such that little if any nuisance would be expected from stack gases even if no fly ash removal were incorporated in the system. However, it is felt that with the fly ash removal system the installation will surely meet the air polution requirements as presently set by the Public Health Department or as may be set in the future.

Breaking-In Period, Initial Operation and Tests

The contractor will be required to furnish competent personnel who will start up the equipment and demonstrate by two days of successful operation at not less than 80% capacity that the equipment is ready to be placed in initial operation. Initial operation will be required for a total of two work weeks during which time adjustments and changes found necessary are to be made. Following initial operation, the contractor will be required to conduct a test run extending over two consecutive days of 24 hours each, during which time the installation is to be operated at various total rates from 50% to 110% of design capacity, varying in extent from 4 hours at 50% to 1 hour at 110%. Additional tests may be required.

As a result of the test run a determination will be made as to whether or not the installation meets the performance requirements. The contract provides for the complete acceptance, conditional acceptance, or rejection of the installation, depending on compliance or non-compliance with the terms and conditions of the warranty.

The cost of the burner, appurtenances and controls, all of which are included under one of the 15 items of the contract amounts to $226,000 as bid. This item includes the designing, furnishing, installing, testing and operating the incinerator and also meeting the stipulated performance requirements.

The contract was prepared by the Construction Division of the Metropolitan District Commission and the completed installation

will be turned over to the Sewerage Division for operation and maintenance as part of the Nut Island Plant.

Present Status of Operation

Presently the incinerator is in partial operation. Grit and screenings are being burned but the burning of scum has not been satisfactorily accomplished.

In an installation of this sort where so many features are involved it requires a tremendous number of adjustments and alterations to get all the components to operate properly at the same time. The controls can be adjusted quite readily where necessary, however, the feeding of the materials into the burner offers the greatest difficulty. Grit was successfully fed to the burner first and burning was satisfactory. Feeding the screenings is being done by means of a special devise which had to be redesigned and rebuilt several times before it could be made to work properly. The feeding device for the scum, particularly the dewatering device is presently being adjusted and may need alterations. It appears that either the vibration cycle is too slow or the scum quantity being fed to it is too great. These factors are being experimented with and it is hoped that the test runs can be started soon. Burning of both the grit and screenings has been self sustaining therefore it is expected the final burning operation will be self sustaining since the scum which will be added later has the highest heat value of the three components to be burned.