Industrial Waste Analysis and Boiler Performance Test Burning Wastes

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ABSTRACT

The ASME Industrial Incineration Sub-Committee is promoting the accumulation of waste-fuel analysis and operating data as a source of information for investigation of present installations. These data will provide a source of scientific information for future designs of waste-burning furnaces. This paper presents detailed analyses of industrial process wastes from the normal manufacturing process in the rubber goods industry. Test results are presented from a boiler burning industrial process wastes, manually batch fed to a reciprocating stoker. The boiler is equipped with a water cooled furnace specially designed for high furnace temperatures.

NECESSITY OF WASTE ANALYSIS

The importance of factual data in the design of furnaces burning industrial wastes with or without heat-recovery units is very obvious to mechanical engineers in the power-combustion field.

In the near future the necessity of waste analysis will become even more important as the enforcement of air pollution laws are applied more forcefully and high cost of installations is going to be scrutinized more carefully. The answer to any problem is determined by the amount of information available about the subject. In the past too much has been done by the early century type of engineering "By guess and by God." Today we cannot afford this type of luxury. Neither do we have the money or the time.

Mr. Elmer R. Kaiser, New York University, has been responsible for much of the work done in the municipal field, gathering and fostering analysis of refuse and sponsoring tests of municipal refuse-burning incinerators.

The industrial field has done little in the promotion of waste analysis and test of industrial burning furnaces. The time has come to encourage industry (a) to analyze its industrial wastes, and (b) to run tests on existing waste-burning installations. Data from such tests should be made public through publication in technical periodicals.

PROBLEMS FACING FURNACE DESIGNERS

The need for factual data is to provide information and guidance for the design of future waste-burning installations.

Present investigations of the operation of furnaces designed to burn industrial wastes show that lack of fact and data on industrial process wastes have produced installations that had no resemblance to the original design concept.

Furnace installations designed from flimsy information did not meet the design specifications. These installations operated with high furnace temperatures and high maintenance costs, while the owners were faced with many pollution problems.

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The industrial furnace designers were not to blame for these shortcomings, because they had to rely on the limited available municipal refuse experience in the design of industrial furnaces. The furnace designers, because of the limited factual data, produced furnaces with unrealistic ratings.

The purpose of a test of a waste-burning installation is to determine the following information:

(a) Adequacy of design concept.*

(b) Contractor meeting design specifications.

(c) Operating efficiency.

(d) Air/water pollution compliance.

In addition to the waste-burning test, operation should maintain a daily log and indicate operating problems as they arise.

The operators should continuously record maintenance and repair costs of the installation for comparison with similar installations and for comparison with the original predicated costs.

SUMMARY OF WASTE ANALYSIS

Waste analysis can be made by laboratories specializing in fuel analysis. The data on physical and chemical characteristics should include:

1) Water content – moisture, percent.
2) Volatile matter, percent.
3) Fixed carbon, percent.
4) Ash content, percent.
5) Heating value, Btu/lb.
6) Corrosiveness – sulphur, chlorine, and so on, percent.
7) Ignition temperature, deg F.
8) Ash-fusion temperature, deg F.
9) Density, lb per cu ft.

Tables 1 and 2 show a summary of industrial waste analysis in the Rubber Industry.

A comparison of industrial wastes with municipal wastes shows that the industrial wastes include a large percentage of materials of high Btu content, close to that of average fuels. The cost of these analyses will be found very much worth the investment.

We hope that in the near future the ASME will consider promulgating Standards for Test Data necessary for the Design of Industrial Waste Burning Installations.

AVAILABILITY OF PLANT WASTES

In addition to the analysis of industrial wastes processed by outside fuel laboratories, it is necessary

*Design concept is the display of principles, particulars, and means necessary to plan a project.

TABLE 1. WASTE FUEL ANALYSIS

Type of Waste	Heating Btu/lb.	Volatiles %	Moisture %	Ash %	Flash Point COC°F	Fire Point COC°F	Sulphur %	Dry Combustible %	Density lbs/cu.ft.
1. Coated Fabric – Rubber	10,996	81.20	1.04	21.20	265	270	0.79	78.80	23.9
2. Royalite	20,299	81.90	0.37	9.62	270	280	0.04	90.38	24.3
3. Coated Felt – Vinyl	11,054	80.87	1.50	11.39	165	170	0.80	88.61	10.7
4. Coated Fabric – Vinyl	8,899	81.06	1.48	6.33	155	175	0.02	93.67	10.1
5. Ensolite – Expanded	10,216	88.90	0.35	9.99	265	300	0.32	90.01	5.7
6. Missile – Rubber Scrap	12,238	71.36	1.69	24.94	340	360	1.17	75.06	28.9
7. Fuel Cell Spray Booth	12,325	79.10	1.74	20.67	125	130	0.25	79.33	9.5
8. Missile – Rubber Dust	9,761	62.36	0.87	36.42	250	260	1.06	63.58	9.9
9. Banbury – Rubber Scrap	13,242	60.51	1.74	4.18	145	180	0.53	95.82	34.9
10. Polyethylene Film	19,161	99.02	0.15	1.49	180	200	0	98.51	5.7
11. Foam – Cloth Backed	10,185	55.06	0.37	31.87	215	235	1.44	68.13	11.3
12. Uppers – Cloth	7,301	70.73	1.25	24.08	295	300	0.40	75.92	13.5
13. Foam – Scrap	12,283	75.73	9.72	25.30	185	240	1.41	74.70	9.1
14. Tape – Resin Covered Glass	7,907	15.08	0.51	56.73	300	330	0.02	43.27	9.5
15. Fabric – Nylon	13,202	100.00	1.72	0.13	625	640	0	99.87	6.4
16. Fuel Cell Bladder and Tire Cord	15,227	87.35	1.24	3.57	270	290	0.55	96.43	19.5
17. Vinyl Scrap	11,428	75.06	0.56	4.56	155	165	0.02	95.44	23.4
18. Liquid Waste	13,140	100.00	3.2	1.04	68	68	0.07	95.76	53.0

NOTE: Test for Volatiles was run independently. The difficulty of getting two similar samples accounts for the higher percentage of Volatiles.

TABLE 2. WASTE FUEL ANALYSIS

	Heating Btu/lb.	Volatiles %	Moisture %	Ash %	Sulphur %	Ignition Temp. °F	Ash Fusion Temp. °F	Density (SP.GR.)
1. Batch Stock (Raw)	14,177	60.29	0.46	13.36	1.07	220	2200	1.112
2. Uncured Frictioned Duck	9,343	76.44	2.57	9.16	0.52	200	2580	0.628
3. Cured Duck	(16,454	69.94	1.47	3.76	1.28	280	2220	0.957
	(11,306	78.08	1.47	11.95	0.86	260	2270	1.004
4. Wire Braid Hose	(12,846	52.13	0.40	11.67	0.87	280	2480	2.109
	(7,820	68.83	2.18	15.30	0.29	220	2500	2.047
5. Uncured C. I.	9,842	55.76	1.73	24.25	1.62	300	2360	1.415
6. Cured C. I.	10,150	49.89	1.66	20.31	0.60	320	2240	1.478
7. Cured Matting Trim	7,228	51.13	0.99	41.47	0.84	300	2240	1.593
8. Packing Trim & C. I.	10,413	53.77	0.99	27.79	0.92	300	2260	1.430
9. Cured Flash & Molded Goods	15,442	62.38	0.91	9.13	0.97	320	2800	1.232
10. Misc. Yarn (Rayon & Cotton)	7,759	90.28	6.59	0.61	0.15	220		0.504
11. Semi-Cured Tubes	15,392	49.70	1.24	2.03	0.70	320	2720	1.279
12. Misc. Tubing & Die Strip	11,352	64.15	0.49	30.54	2.23	300	2120	1.209
13. Rubber Tape	9,629	54.51	0.54	31.63	0.56	280	2460	1.698
14. Ensolex Trim	9,139	65.22	0.40	22.99	0.72	260	2800	0.179
15. Misc. Rubber	11,335	59.42	0.37	23.37	1.50	260	2240	1.252

to have a complete survey of the availability of plant wastes.

The survey usually is started with an initial task by plant production management defining the sources, quantity, and nature of wastes requiring disposal. The survey should include:

(a) Periodic weighing or measurements of volume.

(b) Checking loads of waste hauled away by private contractor to dumping area.

(c) Availability of in-plant waste storage.

These data, together with anticipated future expectancy of plant wastes, current or expected in-plant pickup schedules, and present outside contractor transportation schedules were investigated in determining an economical installation and the furnace burning schedule.

BURNING OF INDUSTRIAL WASTES AT BIRD AND SON, EAST WALPOLE, MASS.

Boiler tests were run with industrial waste burning in a steam boiler at H. Bird and Son, Inc., East Walpole, Mass. The tests were run November 1965 as part of a survey on burning solid wastes in a steam-generating boiler. Figs. 2-4 show various test results.

In 1961 Bird and Son installed a Babcock and Wilcox type H4 No. 12 Sterling boiler with a water-cooled furnace except for the front wall which is wholly refractory. The wastes burn on a 5 ft – 0 in. wide x 8 ft – 0 in. long reciprocating grate stoker. The furnace is also equipped with an auxiliary 16½-in. circular oil burner located on the front wall. A cross section is shown in Fig. 1. The boiler has a capacity to generate 20,000 lb of saturated steam an hour at 150-psig pressure while burning floor linoleum, roofing scrap, and auxiliary fuel oil. The stoker is a standard unit built by Detroit Stoker Company to burn 2000 lb per hr of linoleum and roofing tar paper rejected from the Bird and Son production plant. A 5 ft – 0 in. dia x 185-ft-high steel stack furnishes the necessary natural draft, while two motor-driven blowers provide the necessary combustion air. One of the blowers provides under fire air at 1 to 1.5-in. water pressure and the other provides stoker over fire air at 4 to 6-in. water pressure.

The only automatic boiler control installed is a Bailey furnace-draft controller to regulate furnace draft by controlling the boiler-flue-gas outlet damper.

The waste products are hauled by truck to the boiler house, dumped on the floor in front of the furnace and pushed by the operator manually by means of a hydraulic ram one batch at a time into the furnace. The oil burner is set to maintain a minimum boiler load and in addition it is used as an after burner to assist complete combustion of the volatile gases.

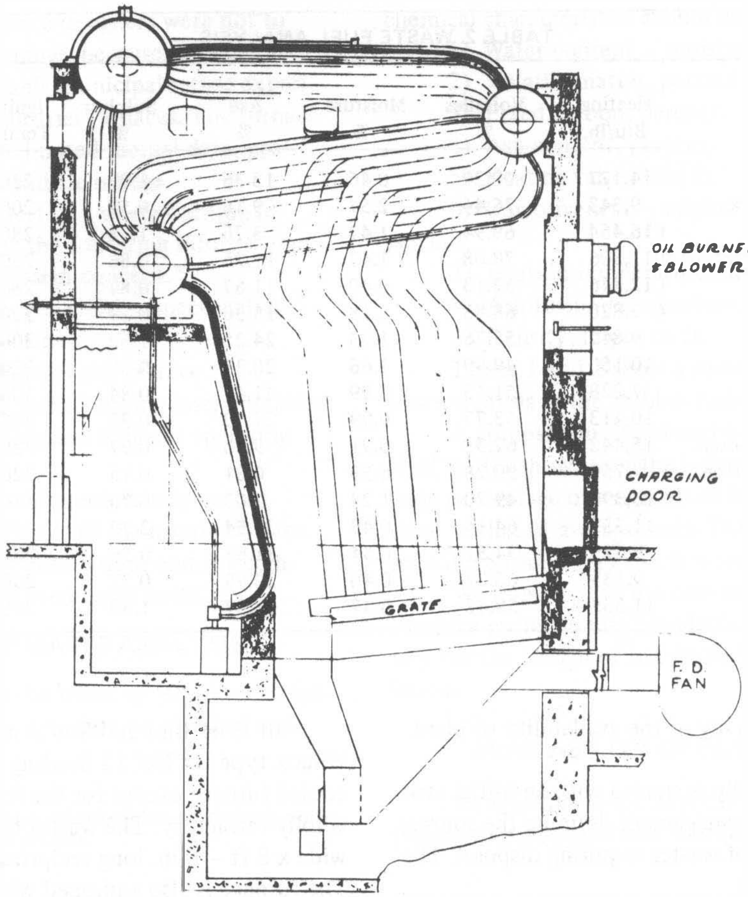

FIG. 1 BABCOCK & WILCOX H-4 NO. 12 BOILER WITH DETROIT RECIPROCATING-GRATE STOKER

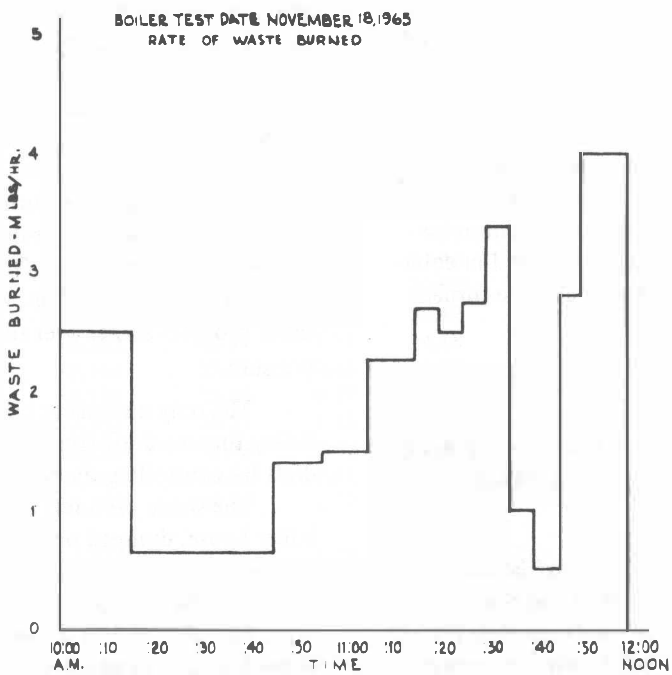

FIG. 2 BOILER TESTS FOR BURNING RUBBER WASTES: RATE OF WASTE BURNED

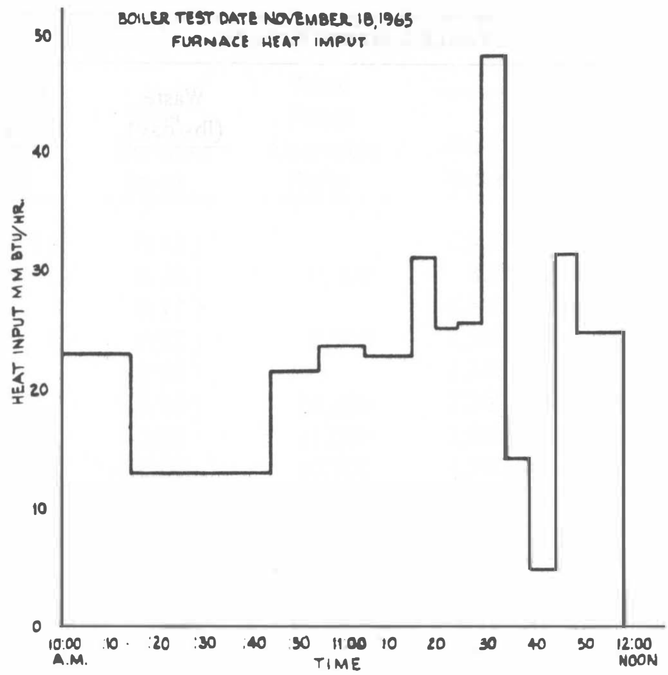

FIG. 3 BOILER TESTS FOR BURNING RUBBER WASTES: FURNACE HEAT INPUT

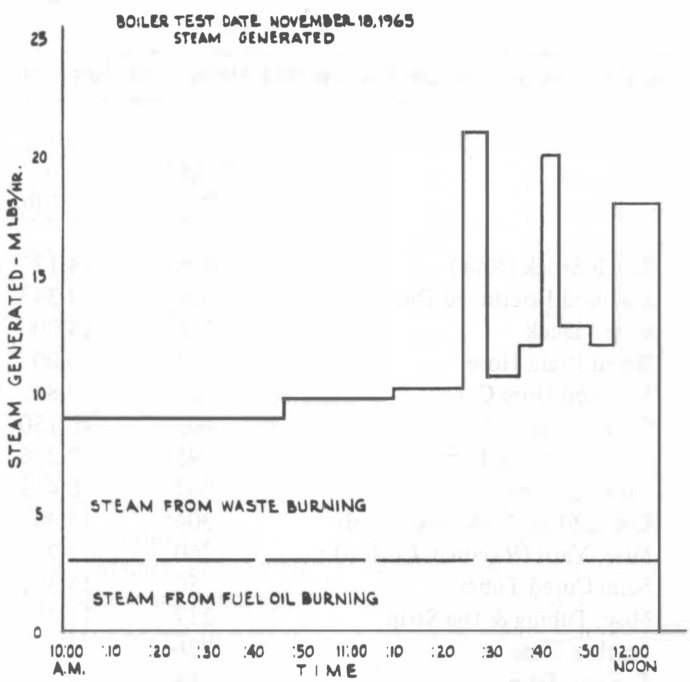

FIG. 4 BOILER TESTS FOR BURNING RUBBER WASTES: STEAM GENERATED

TABLE 3. WASTE SURVEY

Sample Number	Material	Waste (lbs/day)	Waste (lbs/wk.)	Waste-lb. (5 months)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20	Total			
21	Annual Waste – lbs/yr T/yr			

TABLE 4. BOILER CONVERSION – WASTE FIRING; WASTES BURNED

Waste Sample No.		Weight lbs.	Heating Value BTU/lb.	Total Heat MMBTU
1	Batch Stock (Raw)	408	14,177	5.7
2	Uncured Frictioned Duck	320	9,343	3.0
3	Cured Duck	286	14,000	4.0
4	Wired Braid Hose	374	10,000	3.7
5	Uncured Hose C. I.	100	9,842	1.0
6	Cured Hose C. I.	402	10,150	4.1
7	Cured Matting Trim	295	7,228	2.1
8	Packing Trim	202	10,413	2.1
9	Cured Flash & Molded Goods	304	15,442	4.7
10	Misc. Yarn (Rayon & Cotton)	260	7,759	2.0
11	Semi-Cured Tubes	50	15,392	0.7
12	Misc. Tubing & Die Strip	227	11,352	2.6
13	Rubber Tape	226	9,629	2.3
14	Ensolex Trim	58	9,139	0.5
15	Misc. Rubber	240	11,335	2.7
		3.752		41.2

TABLE 5. BOILER CONVERSION — WASTE FIRING; STEAM GENERATED

Test No.	Stock Category No.	Time Duration hours	Total Steam Generated lbs/hr	Stock Feed lbs/hr	Stock Heat Input MMBTU/hr	Stock Steam Generated lbs/hr
1	5, 7, 13	0:15)		2,500	21.6	
2	1	0:30)	9,000	820	11.4	6,800
3	10	0:11)		1,400	21.8	
4	9	0:12)	9,800	1,500	23.5	6,800
5	4	0:10)		2,250	22.2	
6	12	0:05)	10,200	2,700	31.1	7,200
7	8	0:05	21,000	2,500	25.2	18,000
8	2	0:07	10,700	2,750	25.7	7,700
9	3	0:05	12,000	3,400	48.0	9,000
10	11	0:03	20,000	1,000	14.0	17,000
11	14	0:07	12,800	500	4.3	9,800
12	15	0:05	12,000	2,900	31.4	9,000
13	6	0:10	18,000	4,000	24.6	15,000
Average			12,500	1,800	19.2	9,500

Bailey instruments record steam pressure, steam generation, boiler-outlet flue-gas temperature and smoke density. Intermittent batch feeding causes sudden overloading of the furnace resulting in smoking at the beginning of the feed cycle followed by clearing towards the end of the cycle. To feed a furnace manually, one batch at a time, requires: (a) Opening the guillotine door, (b) pushing the wastes slowly into the furnace, and (c) closing the guillotine door. With this type of feeding the furnace is overloaded at the beginning of the cycle, underloaded at the end of the cycle. This type of loading shows the need for continuous waste feeding of uniform size. Equipment to shred, or reduce, to a predetermined size, industrial wastes is being developed and manufactured today.

The removal of ashes is done manually twice a shift by an operator who removes the ashes from the stoker ash hopper and pushes them through a grating located on top of another hopper. The operator removes large clinkers that do not pass through the grating and transfers them to a container. The second hopper is connected to a 4-in. vacuum ash-handling system which takes the ashes to an outside storage bin.

Bird and Son scheduled the burning tests for November 1965. Wastes include limited quantities of the following 15 categories.

Waste Sample No.	Type of Waste
1	Batch stock (raw)
2	Uncured frictioned duck
3	Cured duck
4	Wire braid hose
5	Uncured hose CI
6	Cured hose CI
7	Cured matting trim
8	Packing trim
9	Cured flash and molded goods
10	Miscellaneous yarn (rayon and cotton)
11	Semicured tubes
12	Miscellaneous tubing and die strip
13	Rubber tape
14	Ensolex trim
15	Miscellaneous rubber

The firing of these wastes was started about 10:00 am and continued for about 2 hours until 12:00 noon. Boiler operating data were taken for each waste category in addition to visual inspection of the furnace, stoker and stack emission.

The boiler, a 20,000 lb/hr steam generator, at times reached a steam generation close to 25,000 lb/hr in spite of the fact that the batches of waste being fed into the furnace were kept to a minimum size to prevent overloading of the boiler. The manual batch feeding of the wastes into the furnace was a continuous disturbance to the furnace draft, providing poor boiler operation. In spite of such poor operation the boiler efficiency averaged 50 percent. This test shows that a 60 percent boiler efficiency under continuous waste feeding into the furnace should be attainable with this unit.

The rubber wastes burned so fast that most of the burning took place on the front portion of the stoker. A visual inspection of the ashes showed complete burning of the wastes, resulting in fine ash that could be removed easily and disposed of.

The fuel oil burner was set at a burning rate of about 25 gal per hr. The operators calculated that 3000 lb per hr of steam was generated by the oil burner. This represents a boiler efficiency of about 80 percent.

The attached data and calculations show the burning rates for each category of waste, some being higher than others, because it was hard to manually control the rate of burning. The resulting average steam generated varied from 9000 lb per hr to 21,000 lb per hr. Boiler outlet flue-gas temperatures varied from 550 to 700 F. Steam generation was read off the steam flowmeter chart and calculated from the integrator readings.

DATA AND CALCULATIONS

The attached sheets include:

(a) Test No. 1-13 individual data boiler test sheets.

(b) Summary sheet of wastes burned giving the weights of total batches 1-15 burned in each category, the heating value, and the total heat input of each category into the furnace.

(c) Summary of furnace heat input and steam generated by each category with a resulting average boiler efficiency.

The tests show a wide variation in the rate of heat input. The present basis of design – pounds of waste per hour – is not a true indication of the heat input to the furnace. A heat input rating in terms of Btu per hour is a more realistic unit to be used by designers.

The tests show a great variation in the wastes burned, which in turn causes a great disparity in the rate of heat input.

The present method of feeding the wastes into the furnace without previous processing for uniform sizing and mixing in addition to the existing batch feeding causes problems in the operation of waste-burning installations. The present method of batch feeding without consideration of sizing and mixing presents problems in the control of excess air, combustion efficiency, pollution control, and so on. Present available material-processing equipment does not provide a homogeneous waste of constant quality. Better methods of mixing will have to be developed.

The furnace and heat-recovery designer is faced with a tremendous task to accommodate the primitive way the wastes are fed into the furnace, resulting in a very costly specially designed unit. There is a definite need for the development of equipment to shred, mix the waste, and deliver a homogeneous mixture into the furnace for a minimum capital investment with a low operating expense.

The tests at Bird and Son are very encouraging, where a 50 percent boiler efficiency was recorded in spite of the primitive operation.

We are sure that in the near future boilers burning waste will be equipped with shredders, mixers, automatic handling, and will attain overall efficiencies comparable with present fuel-burning steam generators.