Nozzle Coating and Gun-Barrel Burning in Soda Recovery — Problem and Its Solution

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DEFINITION

The problem of formation of a thick layer of coating on inner side of the barrel of the liquor firing gun and its nozzle has waxed and waned during the past few years. When the coating is formed, it results in the reduced diameter of the barrel and this in turn results in decreased flow of liquor.

The drop in liquor flow due to increased resistance means a lower production from recovery furnace. At times, it can become a bottle-neck to the full utilization of the liquor handling capacity of the furnace due to insufficient liquor feed. Such has been the nature of the problem in Soda Recovery Section of the West Coast Paper Mills Ltd., Dandeli.

CAUSE OF BARREL AND NOZZLE COATING

In practice, two guns are used alternately for firing liquor, one is in operation while the other is being cleaned. Generally, the thickness of coating increases gradually resulting in progressive decrease in the liquor firing capacity. At times, the conditions being favourable, heavy coating can form soon after the installation of the freshly cleaned gun. This would suggest that the coating is not particularly time dependent but is a function of the temperature distribution around the gun-barrel and nozzle. It is also a function of the condition of the gun-barrel and its material of construction. It is to be noted that these days, the barrel burns after 8-12 hours operation or sometimes even earlier.

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During normal operation, the radiated heat from the furnace is transferred to the firing liquor flowing through the barrel. However, with the formation of insulating coating, the heat dissipation from metal to liquor is prevented. This results in exceeding the smelting temperature and the metal from the gun-barrel is dissolved by the molten mixture. A large hole is thus punctured in the barrel rendering the gun useless for further operation and its replacement is made immediately. The temperature in the liquor firing zone is around 900°C and the melting point of mild steel is about 1500°C. Only the theory of flux formation can explain the burning of gun-barrels at such a low temperature.

The problem of burning holes in the gun-barrel is accentuated by the present practice of patching up the hole instead of replacing the barrel. This is illustrated in **Fig. 1.** The welding of a patch creates a pocket and a stagnant layer of liquor is formed which carbonizes, smelts and fluxes with the metal burning a hole through the barrel. Therefore, if the barrel is cut at A and a new piece is attached, the coating and consequent burning of the barrel should take much longer time as there is no rough surface or pocket to accummulate liquor. Though the cost of barrel replacement is estimated at Rs. 30/- as against a patch-up job of Rs. 25/-, yet the former practice should prove cheaper due to lesser number of replacements.

The data on the burning of gun-barrels are given in **Table I.** On an average, about 38 gun-barrels got burnt during each month, costing about Rs. 1,000/- per month for repairs. In addition, it is estimated that about 10 tons of fuel oil need to be fired during the month for these replacements which costs about Rs. 2,500/-. A part of this oil consumption can be reduced if the burning of gun-barrel can be avoided. The down-time due to

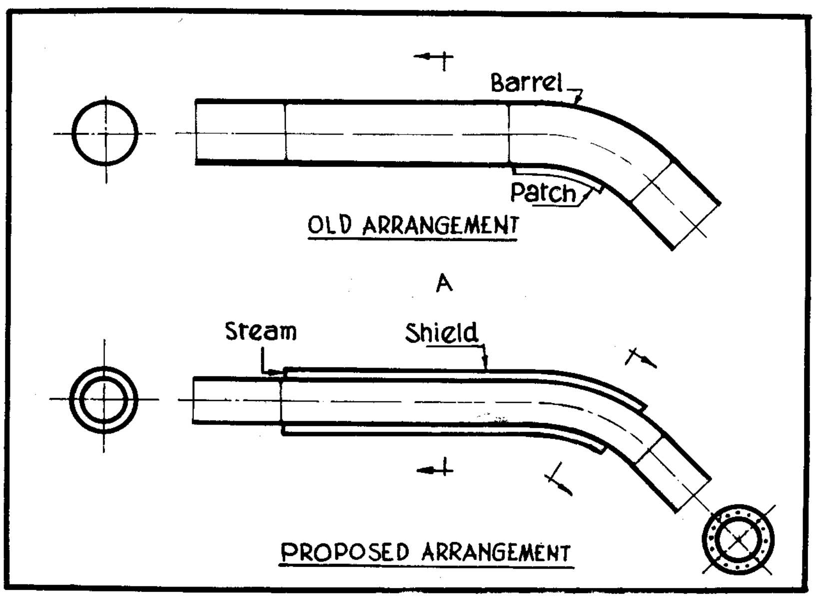

Fig. 1. Gun Barrel in Soda Recovery Section.

Table I Gun-barrels Burnt During 1969 in Soda Recovery

Date	Month: Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
1	1	4	1	2	1	— *	—	—	6	1
2	1	1	2	1	—	—	—	3	5	1
3	1	1	1	2	3	—	1	—	2	2
4	2	—	3	2	2	—	3	—	1	1
5	6	2	2	—	3	—	1	—	4	1
6	6	—	3	1	—	—	6	2	1	1 **
7	— *	—	—	—	1	1	2	1	1	—
8	—	2	1	1	1	1	4	1	1	—
9	3	1	2	1	—	—	2	—	1	—
10	2	2	3	3	1	3	— *	—	4	—
11	1	—	1	1	—	—	—	2	—	—
12	2	1	—	3	—	—	1	1	3	—
13	—	2	—	3 *	2	1	2	— *	3	—
14	2	1	—	—	—	2	—	—	3	—
15	1	—	—	—	—	4	2	—	—	—
16	2	2	2	—	—	—	3	—	—	—
17	1	3	1	—	—	4	2	—	—	—
18	3	—	—	1	—	1	2	—	2	—
19	1	—	1	1	—	—	1	—	—	—
20	2	— *	2	—	1	1	1	—	2	—
21	2	—	3	2	—	—	—	—	3	—
22	3	—	2	—	—	—	—	—	1	—
23	5	3	—	—	—	—	—	2	4	—
24	2	—	—	—	1	1	2	—	3	—
25	6	2	1	—	—	3	—	—	2	—
26	2	—	—	2	1	1	1	1	1	—
27	5	—	2	—	—	2	2	—	1	—
28	4	1	2	—	—	4	1	3	3	—
29	2	—	1	—	1	6	—	1	1	—
30	2	—	1	1	—	1	1	2	2	—
31	1	—	2	—	—	—	2	2	—	—
Total:	70	28	38	27	17	33	42	23	60	—

* Shut-down

** Prior to this date 1½" dia. barrel was used. Installation of 1" dia. barrel gun has resulted in nogun-barrel burning since then.

TABLE II Soluble and Insoluble Organics in Barrel and Nozzle Coatings

Source of sample Analysed for/	Gun-Barrel Sample A	Gun-Barrel Sample B	Nozzle Sample A	Nozzle Sample B
1. Hot water insolubles	13.9	10.9	18.3	12.7
2. Inorganics* in 1	2.0	1.4	1.7	2.0
3. Organics* in 1	11.9	9.5	16.6	10.7
4. Loss on ignition** (at 700°C)	17.5	17.0	22.2	20.1
5. Soluble organics***	5.6	7.5	5.6	9.4

N. B. All results are expressed on per cent oven dry basis.

* Inorganics and organics were determined by igniting the hot water insoluble residue.

** This is assumed as total organics.

*** This is obtained by subtracting 3 from 4.

change-over of guns is reduced and more liquor can be fired during this period.

SUPPORTING DATA

To check the chemical composition of the coating formed in the gun-barrel and its nozzle, analyses were done on two separate samples. The guns were cooled by blowing steam before withdrawing from the furnace. The loss on ignition was only 17-22% on the moisture free sample basis. This indicated that the carbonization of the coating took place. The results are given in **Table II.**

The data in Table II indicate that the major portion of the hot water insolubles are carbonized organics. The soluble organics are low and part of this may be due to adhering and/or entrained firing liquor.

Analyses were done on the ash (obtained by igniting the samples at 700°C) to determine the nature of the inorganic salts present in the coatings and the firing liquor. The data in **Table III** show that the composition of the coatings and the firing liquor are similar in respect of active alkali. The Na_2SO_4 content of the coating is lower suggesting that it was not precipitating out. However, there was a greater percentage of SiO_2 in the coatings as compared to the firing liquor.

REMEDIAL MEASURES AND THEORETICAL CONSIDERATIONS

From the above discussion, it is clear that the pockets created by patch-up repairs cause greater incidence of coating and barrel puncturing. Of course, this can be avoided by using new barrels. Now the question arises how to prevent or reduce the formation of coating. It is clearly a problem on heat-transfer as indicated by the carbonization of coating. The nozzle and the portion of the barrel protruding into the furnace are in a temperature zone of about 925°C while the temperature of the liquor is at 112-114°C. Due to such a large temperature difference, nucleate boiling can take place resulting in the formation of a superheated vapour film of low thermal conductivity resulting in decreased heat dissipation from metal to liquor. The barrel attains the temperature of the furnace and chars the layer of liquor adjacent to it. This carbonized liquor coating further reduces the heat dissipation and

TABLE III Constituents of Ash from Barrel and Nozzle Coatings and Firing Liquor

No.	Source of ash Analysed for*	Gun-barrel Sample A	Gun-barrel Sample B	Nozzle Sample A	Nozzle Sample B	Firing Liquor
1.	NaOH	6.9	9.9	7.2	10.1	5.6
2.	Na_2S	1.3	1.9	1.8	2.3	1.9
3.	Na_2CO_3	65.0	60.0	66.0	60.0	63.2
4.	Na_2SO_4	9.5	9.5	9.6	10.4	15.3
5.	SiO_2	12.2	17.3	11.4	15.2	6.3
6.	NaCl	2.0	1.2	4.1	2.0	9.4

* The data were calculated as percentage of ash.

the thickness of coating increases. The operation under these conditions can form smelt at the inner surface of the barrel resulting in fusion of metal and puncturing.

Consequently, there arise two possible solutions to the problem. One is a curative solution, the other a preventive. A combination of both may also be considered. Under the first system, the velocity of liquor flow can be increased by reducing the barrel diameter. The increased turbulence provides self-cleaning action on the inside surface of the barrel. Reynold numbers have been calculated for 1″, 1¼″ and 1½″ diameter, schedule 80 pipes which may be used for the gun-barrel.

BASIC DATA

Flow rate : 10.8 cu m/hr

I.D. of pipe : 2.43 cm, 3.12 cm or 3.81 cm

Viscosity of liquor : 35 cp

Density of liquor : 1.3 kg/litre

$$Re = \frac{DVP}{u}$$ where

Re = Reynold number

D = diameter of pipe, m

V = velocity of flow, m/sec.

P = density, kg/litre

u = viscosity, Kg/(m) (sec.)

$$\text{Re for 1'' dia.} = \frac{0.0243 \times 6.47 \times 1300}{0.035} = 5840$$

$$\text{Re for } 1\tfrac{1}{4}'' \text{ dia.} = \frac{0.0312 \times 3.92 \times 1300}{0.035} = 4540$$

$$\text{Re for } 1\tfrac{1}{2}'' \text{ dia.} = \frac{0.0381 \times 2.63 \times 1300}{0.035} = 3720$$

The values of Re show that the flow is turbulent in all the three cases and for increase of Re from 3720 to 5840, the heat transfer co_efficient does not improve by more than 10%. There is some increase in the frictional loss with the decreasing diameter of the barrel. The loss of head due to friction has been calculated by means of the Fanning equation:

$$h = \frac{fLv^2}{2gD}$$

where h = head loss due to friction, m

f = friction factor determined experimentally in relation to Reynold number. The values were taken from Cameron Hydraulic Data.

L = length of gun-barrel, m.

v = velocity of flow, m/sec

g = 9.81 m/sec²

D = diameter of pipe, m

$$\text{h for 1'' dia.} = \frac{0.038 \times 0.56 \times (6.47)^2}{2 \times 9.81 \times 0.0243} = 1.87 \text{ m}$$

$$\text{h for } 1\tfrac{1}{4}'' \text{ dia.} = \frac{0.040 \times 0.56 \times (3.92)^2}{2 \times 9.81 \times 0.0312} = 0.56 \text{ m}$$

$$\text{h for } 1\tfrac{1}{2}'' \text{ dia.} = \frac{0.042 \times 0.56 \times (2.63)^2}{2 \times 9.81 \times 0.0381} = 0.22 \text{ m}$$

The firing liquor is pumped with a pressue of about 20 metres. Therefore, for pumping the same quantity of liquor, an increase of head by only 8% is required in the case of 1″ dia. barrel as compared to 1½″ dia. barrel. In actual practice, it should be possible to fire liquor at the rate of 11 cu m/hr through these different barrel sizes.

The preventive method consists of providing an arrangement so that the carbonization of the liquor in the gun-barrel is prevented. Using 1″ dia barrel, a tubular shield can be provided passing steam through it. A flexible steam hose connection shall be needed for this purpose. Such an arrangement should keep the barrel and shield at low temperature and prevent carbonization of liquor and formation of coating in the gun-barrel.

CONCLUSION

1 The practice of patch-up repairs of gun-barrel is not economical and should be discontinued. Instead, new barrel piece should be welded. The patched-up barrels have greater incidence of puncturing by fusion.

2 Liquor firing gun with 1″ dia barrel should give about 11 cu.m./hr. with an additional head loss of 1.9 m only and should be suitable for this capacity. The increased turbulence should produce self-cleaning action and prevent accumulation of coating.

3 Since 6th October the date of installation of 1″ dia barrel gun without shield, there has been no burning of the same and the operation is reported to be satisfactory.

4 To prevent the formation of coating completely, it may be worthwhile to try shielding the barrel with steam flowing around it which should prevent carbonization of liquor in the barrel.