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ENERGY SAVING THROUGH INTELLIGENT SOOTBLOWING: A CASE STUDY

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Abstract:

The success of deposit removal by a sootblower depends on two main factors; (1) the sootblower jet cleaning power and (2) the sootblowing timing. Much research has been dedicated to optimize the sootblower jet cleaning power in a form of an improved sootblower nozzle design, but little has been done to answer the questions of when each sootblower should be optimally run and of what will be the appropriate cleaning intensity. Although many pulp mills have equipped their sootblowers with high efficiency nozzles, most recovery boiler sootblowers are still run without the real-time feedback information of where the fouling may be located. The knowledge of optimum sootblowing timing will not only reduce costly sootblower steam consumption, but also improve the recovery boiler thermal efficiency and prevent sootblower-induced-tube erosion. This paper discusses a case study involving a pulp mill in Northwest USA where (1) mass and energy balances were set around each of the recovery boiler heat exchanger and (2) deposit weight accumulation measured by means of Fouling sensors installed on the boiler hanger rods to identify fouling intensity, to measure sootblowing effectiveness, and to intelligently manage the sootblower operation.

Keywords: Recovery boiler, Plugging prevention, Runtime extension and Steam savings

Introduction

The accumulation of fireside deposits on recovery boiler heat transfer surfaces not only creates an insulating barrier that reduces the boiler thermal efficiency, but can also lead to costly unscheduled shutdown due to the plugging of the gas passes. Control of the deposit accumulation is attained by sootblowers, which periodically blast deposit off the tube surfaces with high pressure superheated steam.

The success of deposit removal by a sootblower depends on two main factors: (1) the sootblower jet cleaning power and (2) the sootblowing timing. Much research has been dedicated to optimize the sootblower jet cleaning power in a form of an improved sootblower nozzle design, but little has been done to optimize the sootblowing timing.

Material and Method

Most pulp mills run their sootblowers based on a static predetermined sootblowing sequence. This sequence is generally pre-tuned to deal with a fouling condition under the designed black liquor firing load. The sequence is independent of the real fouling conditions inside the boiler, hence, there is always a high risk of over and/or under cleaning. Over cleaning will lead to high sootblower steam consumption and sootblower-induced-tube erosion, while under cleaning will lead to heavy fouling and plugging.

When a deposit is still in an early stage of development as seen in Figure 1, it is very unlikely that the deposit can be removed by a sootblower jet. This is due to the fact that the jet/deposit contact

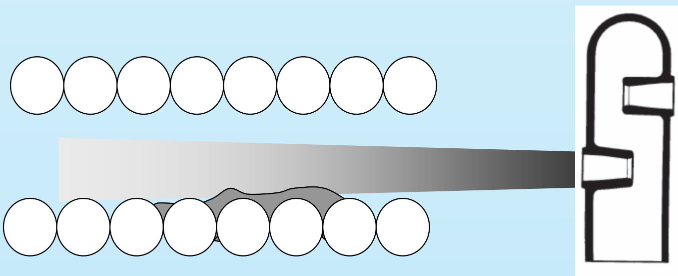

Figure 1 Sootblower operation when the deposit is still in an early stage of development (Wasted Steam)

area is very small to develop any significant removal force. It is true even if the jet has a very high cleaning power. Hence, in this condition, it can be expected that the sootblower operation is ineffective and the valuable sootblower steam is wasted.

On the other extreme, plugging of the gas passes is inevitable if the sootblower is in idle position for an extended period of time. The deposits can bridge the gap between the tube banks, making it harder to be removed by a sootblower jet (Figure 2).

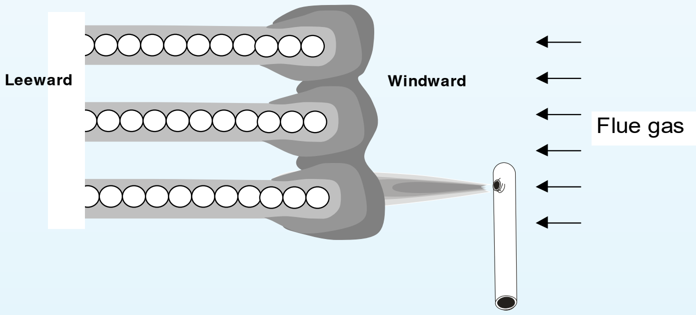

Figure 2. Sootblower operation when the deposit has grown into a large size

In between these two extremes, there exists optimal sootblowing timing. Since deposit accumulation in recovery boilers is a dynamic event where the rate of accumulation and the stickiness of the deposit depend on many factors, the optimal sootblowing timing can only be achieved through an automated closed loop sootblower control system that uses fouling feedback information gathered online, during normal boiler operations, to intelligently manage the sequence of sootblowing operation.

In this paper, a method to detect the fouling intensity by means of energy balance around heat exchangers will be discussed and how such information can be used to measure the sootblowing effectiveness and optimize the sootblowing timing. A case study involving a pulp mill in the Northwest of USA will also be discussed where the implementation of the system is presented and the benefits are evaluated. This system will be referred to Intelligent Sootblowing system or ISB throughout this paper.

FOULING DETECTION

Direct Deposit Weight Accumulation Measurement: Most recovery boiler heat exchangers are supported by hanger rods. When the deposit accumulates in the heat exchanger fireside tube surfaces, the load experienced by the hanger rods increases. By measuring the stretch in the hanger rods due to this load increase, we would be able to determine the location of the deposit accumulation, its intensity, and manage sootblowing operation accordingly to save steam and prevent heavy fouling. Figure 3 shows the Fouling sensors installed on the recovery boiler hanger rods

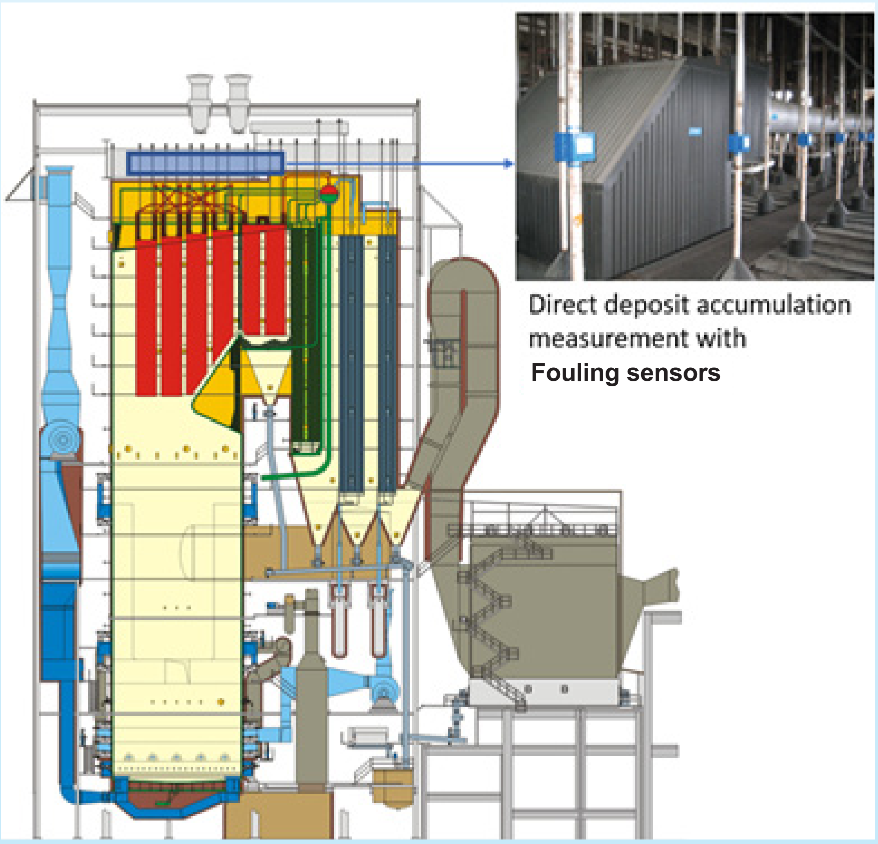

Figure 3. Fouling sensors installed on recovery Boiler Hanger Rods

Mass & Energy Balances: Fouling in the heat exchanger tube surfaces will reduce the heat transfer efficiency of the exchanger. The direct relationship between the fouling and the decrease in the heat transfer efficiency is the main tool used by the ISB to measure the sootblowing effectiveness in removing deposits and to detect the location and the severity of the deposit.

The heat transfer efficiency of a heat exchanger is defined as the ratio of the actual heat transferred to the water or steam inside the heat exchanger to the total available heat input to the exchanger.

$$\eta = \frac{\text{Actual heat transfer to the water/steam inside the heat exchanger}}{\text{Total available heat input to the heat exchanger}} = \frac{Q_{Actual}}{Q_{Heat\ Input}} \quad (1)$$

Actual Heat Transfer to the Water/Steam

The actual heat transfer to the water or steam inside the heat exchanger is calculated as the difference between the enthalpy of the steam entering and exiting the exchanger. Figure 4 illustrates the control volume used to calculate the heat transferred to the primary superheater section of a recovery boiler.

$$Q_{Actual}\text{ (primary superheater)} = (m\ H)_{steam\ inlet} - (m\ H)_{steam\ outlet}$$

where m is the mass flow rate and H is the enthalpy. Note that all of the mass and heat inputs to the steam side of control volume need to be accounted. For the case where the exchanger receives an attemperation flow, the QActual becomes

$$Q_{Actual} = (m\ H)_{Steam\ inlet} + (m\ H)_{Attemperator\ flow} - (m\ H)_{Steam\ outlet}$$

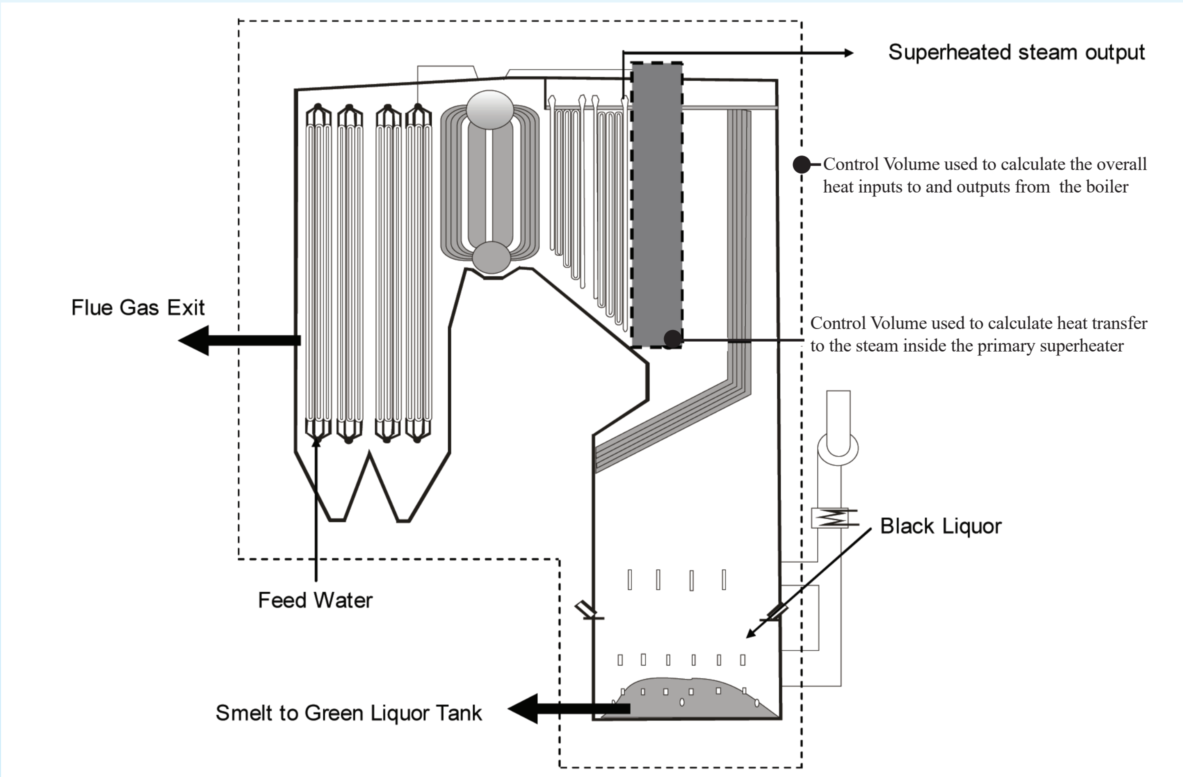

Figure 4. Mass and Energy Balances Boundaries

To calculate Q_{Actual}, the mass and the enthalpy of all flows entering and leaving the control volume have to be known. The mass flow rates of the steam and attemperation flows are generally readily available but the enthalpies are not. The steam temperature and the pressure are the two parameters required to calculate the enthalpy. Although the steam pressure can be reasonably estimated based on the feed water pressure and the pressure drops along the heat exchangers, the steam temperatures have to be directly measured.

Two most common methods of measuring the steam temperatures entering and exiting the control volume are (1) the thermal wells drilled in the tubes entering and leaving the heat exchanger or (2) the thermocouples attached to the skin of the tubes entering and leaving the heat exchanger (Figure 5).

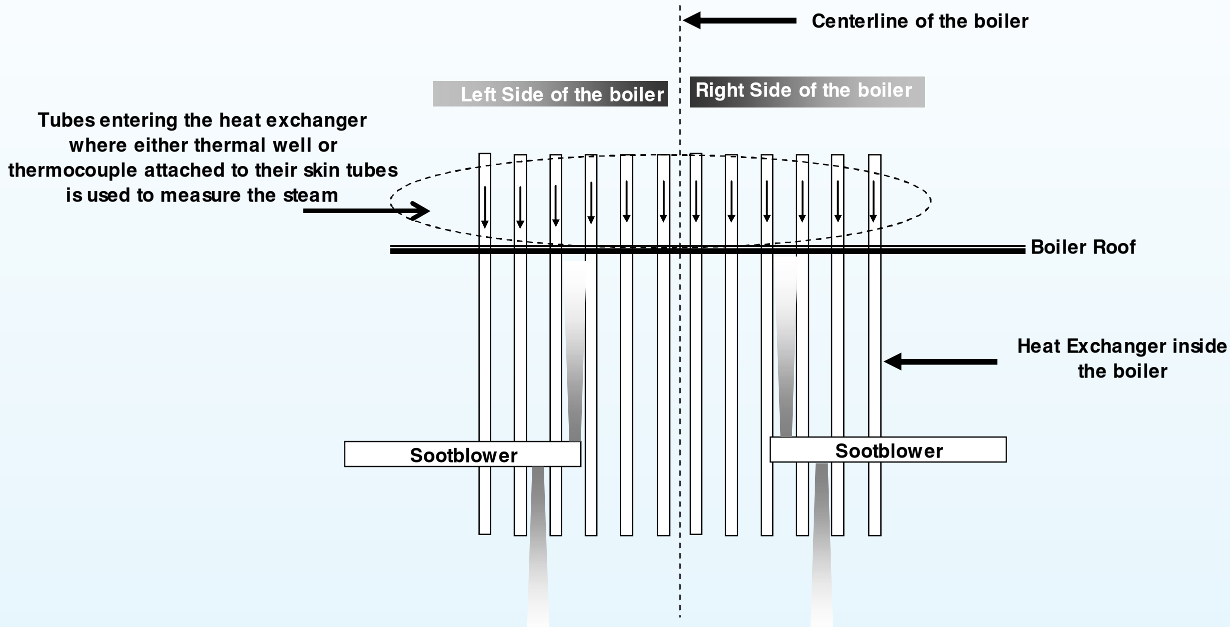

Figure 5. Location of the thermal wells to measure the steam temperatures entering a heat exchanger

If the sootblowers are not equipped with dual motors, SmartSootblower [1] with the capability to maneuver the transversing and rotating motions of its lance tube independently, the ISB will use the average steam temperatures in the left and the average of the temperature in the right to calculate the Q_{Actual} in the left and right side of the boiler.

Many recovery boilers have already had these steam temperature measurements as part of the recovery boiler safety initiative to detect the possibility of tube overheating during the startup where the tubes receive the full heat from the boiler without water/steam present inside the tubes. Hence, most of the ISB installation did not require additional purchase of steam temperature measurements.

Total Available Heat Inputs

There are four sources of heat inputs to a recovery boiler. They are (1) Heating value of the black liquor solids, (2) Sensible heat of the black liquor, (3) Sensible heat of the air, and (4) Heating value of the auxiliary fuel (if any). The heating value of the black liquor solids is by far the most significant heat input to the boiler, which account for about 90% of the total heat inputs. It is the energy released by the combustion of the black liquor organics. To calculate the total heat inputs and outputs, the overall recovery boiler control volume boundaries as shown in Figure 3 is used. Detailed of the total heat inputs calculation can be found in reference [2].

To calculate the available total heat input supplied to the heat exchangers, we start with the available heat input to the first pass of the superheater (i.e., the first heat exchanger in the convection section of the boiler immediately after the flue gas exiting the furnace section). The heat input to the first pass of the superheater is the total heat inputs to the boiler minus the following heat losses:

1. Moisture in the flue gas sensible heat
2. Latent heat of water in the black liquor
3. Latent heat of water from combustion
4. Heat content of smelt
5. Heat content of sulfide
6. Heat loss to combustibles in flue gas
7. Heat loss due to unburned carbon (carbon in smelt)
8. Radiation loss
9. Unaccountables (assumed to be 1% of the total heat inputs).

The available heat input to the second pass of the superheater is the total heat input available to the first pass of the superheater minus the actual heat transfer to the steam inside the first pass of the superheater, and so on.

Once the actual heat transfer to the water/steam and the total available heat to the exchanger are obtained, the heat transfer efficiency of each of the heat exchanger (η) can then be calculated using equation 1.

The ISB uses η to detect the degree of fouling in the exchanger. Downward trend of indicates that the cleanliness of the heat exchanger is deteriorating. On the other hand, upward trend or upward spike immediately after sootblowing indicates that there is an improvement in the exchanger cleanliness. The effectiveness of the sootblower in removing deposit is measured by how much improvement it can make to the η .

CASE STUDY

In this case study, the discussion is focused on the Intelligent Sootblowing ISB installation on a 1992 ABB CE Single drum recovery boiler designed to burn 3.7 Million lb/day Black Liquor Dry Solids. The boiler produces 650,000 lb/hr steam at 825 psig and 750 oF. Before the installation of the system, the sootblowers consumed 28,000 lb/hr valuable steam. With the cost of steam around US $9/1000lb ($20/ton), the sootblower steam consumption costs the pulp mill around $2 Million / year.

The main motivation of installing the system is to reduce the sootblower steam consumption without the sacrificing the cleanliness of the recovery boiler.

Figure 6 shows the Fouling sensors measurements and the heat transfer efficiency of the primary superheater section. The vertical lines are the sootblowing events. As seen in this Figure, when the deposit accumulation reach the dirty setpoint and/or the heat transfer efficiency dropped to the dirty setpoint, the most effective sootblowers (based on the historical data) are sent to clean the area. With this strategy, the amount of steam used for sootblowing is directly proportional to the degree of fouling and the boiler cleanliness is maintained at acceptable level.

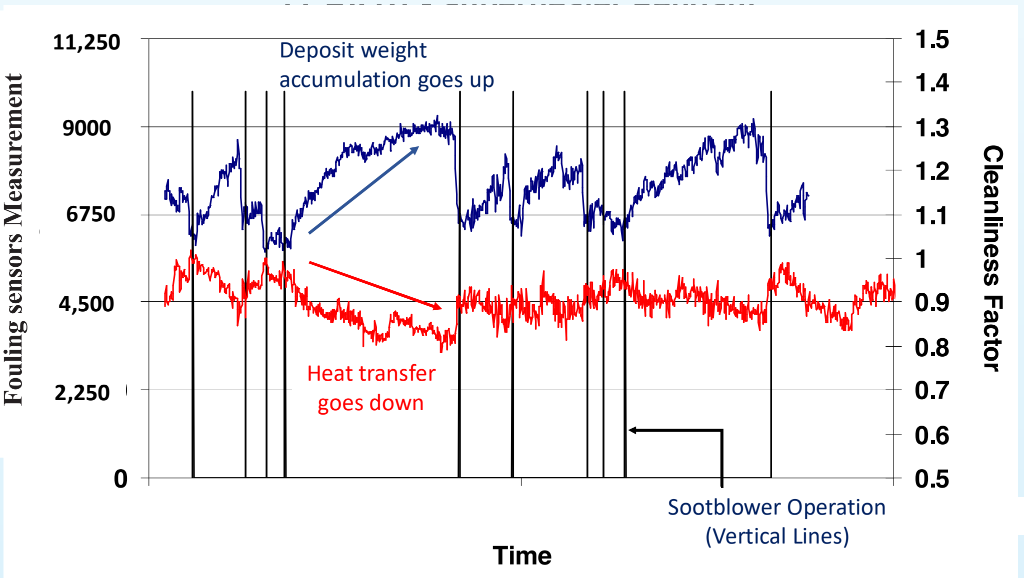

Figure 6. Fouling sensors measurement & Heat transfer efficiency of the 1st superheater section as a function of time

Figure 7 shows the drop in the sootblower steam consumption, constant ID fan speed (i.e., no heavy fouling/plugging was detected) even in the event that the black liquor flow was increased. The steam consumption dropped from 28,000 lb/hr to 18,000 lb/hr, saving 10,000 lb/hr worth around $760,000/yr.

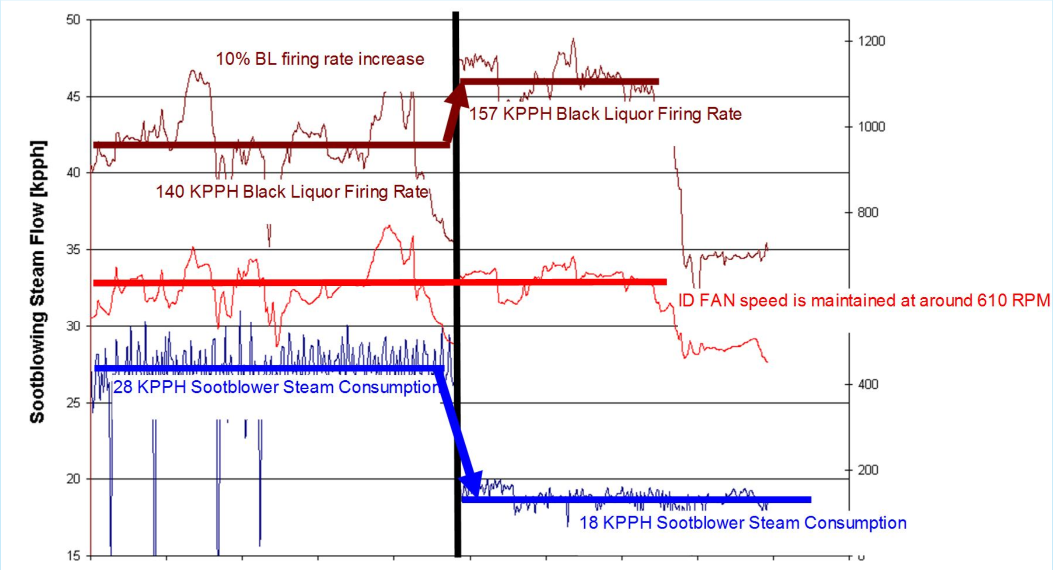

Figure 7. Steam Consumption, ID Fan Speed, and Black Liquor Flow

CONCLUSION

The success of deposit removal by a sootblower depends on two main factors: (1) the sootblower jet cleaning power and (2) the sootblowing timing. Since deposit accumulation in recovery boilers is a dynamic event where the rate of accumulation and the stickiness of the deposit depend on many factors, the optimal sootblowing timing can only be achieved through an automated closed loop sootblower control system that uses fouling feedback information gathered online, during normal boiler operations, to intelligently manage the sequence of sootblowing operation.

A method to detect the fouling intensity by means of direct deposit weight accumulation measurement through Fouling sensors and energy balance around heat exchangers have been discussed and it was shown that how such information can be used to measure the sootblowing effectiveness and optimize the sootblowing timing. A case study involving a pulp mill in the Northwest of USA is presented where the implementation of the system is discussed and the benefits are evaluated.

Intelligent SootBlowing (ISB) using online fouling feedback information has been shown to successfully reduce the sootblower steam consumption without sacrificing the cleanliness of the boiler.

REFERENCES

1. Tandra, D.S., Shah, S., “Extended Recovery Boiler Runtime Using Smart Sootblower”, TAPPI Engineering, Pulping, and Environment Conference, Atlanta, GA, USA (2006)
2. Tran, H.N., “Kraft Recovery Boilers”, edited by T.N. Adams et al, TAPPI Press (2020)