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APPLICATION NUMBER: *62/540,763*
FILING DATE: *August 03, 2017*
RELATED PCT APPLICATION NUMBER: *PCT/US18/45264*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US62/540,763*

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METHOD FOR CONTROLLING INTAKE COUNTER FLOW SEEN DURING HPD TRANSIENT

FIELD

The present invention relates generally to a system and method for engine braking, and more particularly, a control strategy to sequence the main event exhaust valve motion cancellation using a braking hydraulic circuit.

BACKGROUND

Internal combustion engines typically use either a mechanical, electrical, or hydro-mechanical valve actuation system to actuate the engine valves. These systems may include a combination of camshafts, rocker arms and push rods that are driven by the engine's crankshaft rotation. When a camshaft is used to actuate the engine valves, the timing of the valve actuation may be fixed by the size and location of the lobes on the camshaft.

For each 360 degree rotation of the camshaft, the engine completes a full cycle made up of four strokes (i.e., expansion, exhaust, intake, and compression). Both the intake and exhaust valves may be closed, and remain closed, during most of the expansion stroke wherein the piston is traveling away from the cylinder head (i.e., the volume between the cylinder head and the piston head is increasing). During positive power operation, fuel is burned during the expansion stroke and positive power is delivered by the engine. The expansion stroke ends at the bottom dead center point, at which time the piston reverses direction and the exhaust valve may be opened for a main exhaust event. A lobe on the camshaft may be synchronized to open the exhaust valve for the main exhaust event as the piston travels upward and forces combustion gases out of the cylinder.

The above-referenced main exhaust valve event is required for positive power operation of an internal combustion engine. Additional auxiliary valve events, while not required, may be desirable. For example, it may be desirable to actuate the exhaust valves for compression-release (CR) engine braking, bleeder engine braking, exhaust gas recirculation (EGR), brake gas recirculation (BGR), or other auxiliary valve events.

In known 2 stroke braking systems a collapsing element is used to cancel the primary main event valve motion on the intake and exhaust while adding a secondary valve motion to one or more of the intake and/or exhaust valves. Another known variation of the 2 stroke braking system is 1.5 stroke braking. 1.5 stroke braking cancels the primary main event motion on the exhaust while adding a secondary braking motion on one or more of the exhaust valves while the primary intake valve motion remains unchanged.

During transient activation and deactivation loads, exceeding steady state can occur on the intake valve train and can last for one or more cycles of the engine. This loading is caused when the main event exhaust motion has been cancelled but the braking piston has not been allowed sufficient time to fully index. This results in a low lift "failsafe" event from the braking rocker, which cannot evacuate enough air from the cylinder as the main event exhaust lift can. As a result, the intake rocker will open one or more valves against higher than normal cylinder pressure, resulting in high load to the intake rocker and valve train as well as high pressure air into the intake manifold. This abnormally high intake event also results in a high-pressure pulse being sent to the intake manifold. This pulse can lead to undesirable effects such as intake counter flow and turbo surge. This "failsafe" event is a known feature of the 1.5 stroke brake system that is used to reduce the intake cylinder pressure in this transient condition. Unfortunately, loads are still higher than steady state for the intake system even with the failsafe.

DETAILED DESCRIPTION

In order to provide an improved engine braking system and to overcome the disadvantages and problems of currently available devices, there is provided a system and method for sequencing of the solenoids that turn on the brake and collapse the exhaust main event. A particular advantage of the new and novel system described herein is the elimination or reduction of high intake valve train loading. Another advantage is the elimination or reduction of high pressure air released into the intake manifold, which causes a short loud noise (noise pollution) as well as possible negative impacts to the turbo charger and overall mass airflow of the engine. Still another advantage is elimination or reduction turbo surge that can be seen during HPD transient Events. The resulting benefits may include a possibly smoother/quieter transient, safer operation with a turbocharger, and increased engine reliability. Other benefits may result as well.

In a High Power Density braking system, it may be necessary to reduce or control the high pressure intake opening event during transient brake activation conditions that can lead to high intake valve train loading, gas counter flow into the intake stream and turbo surge results from the gas counter flow. This can be done either by staggering the brake motion and the main event collapsing motion turn on/off times, for a 1 valve opening system, or with the use of intake throttle and/or EGR, for a 2 valve opening system.

For a 1 valve opening system the high pressure intake event and subsequent gas counter flow can be reduced or avoided by sequencing the activation of the brake circuit to the activation of the exhaust main event collapsing circuit. When both circuits are activated simultaneously, as shown in FIG. 1, the exhaust main event is cancelled immediately while the brake actuator has not been fully deployed. This results in a much smaller volume of air being able to escape the cylinder during the small BGR event as compared to the normal main event exhaust, leading to abnormally high intake load. FIG. 2 shows the delay that allows the piston to fully deploy before collapsing the main event. By adding a pre-defined delay between the 2 circuits in which the brake is activated first then the exhaust collapsing mechanism, the brake is allowed to fully deploy before the main event exhaust is cancelled. In this case, once the main event exhaust motion is cancelled, the loading on the intake rocker is equivalent to the loading that the intake rocker will see during steady state operating conditions of the brake.

For a 2 valve opening system, intake counter flow to the turbo compressor can be controlled by the use of intake throttle and/or EGR valve system. It would be necessary to time the closing of the intake throttle and/or opening of the EGR circuit to coincide with the timing of the intake counter flow pulse seen during a transient condition. The intake throttle could act as a type of door to instantaneously block the mass flow from reaching the compressor wheel, while the EGR circuit will act as an accumulator/damper to attenuate the counter flow pulse. Use of the EGR circuit could also promote flow directly into the exhaust manifold, therefore increasing mass flow through the compressor and reducing the possibility of compressor surge. Once this event ends, the intake throttle would fully open, the EGR circuit would return to normal, and the system would operate in normal steady state.

In operation, during brake activation the brake solenoid is activated first. This allows the brake piston to start to extend before the main event is cancelled. After a predetermined time when the brake pistons have been allowed to fill, the solenoid that controls the main event collapse is activated, cancelling the exhaust main event motion. By allowing the brake piston to fully or partially extend

before the main event is cancelled the braking valve motion is closer to what it would be during steady state braking with 1 or 2 CR and BGR events in addition to the "failsafe" motion. Note that the failsafe is the BGR event, but just lower because the brake is off. As such, when the brake extends, the failsafe becomes bigger and is itself the BGR event in braking. Subsequently, the duration and amplitude of the high intake loading during brake activation is reduced. The required duration for the delay can depend on many factors so a calibration for each engine platform may optionally be done to increase accuracy. Delay duration may also vary with engine speed so the desired duration may vary depending on engine speed and oil pressure. Again, an optional fixed time delay for all engine speeds may also be implemented.

The delay itself may be implemented in several ways. For example, the delay could be integrated into the engine control unit (ECU) control logic. In an alternate embodiment, an external control box between the ECU and solenoids could also function to implement the delay. In another embodiment, a fixed delay unit could be integrated into the wire that controls the solenoid without any need for control logic or computer programming.

Furthermore, it is to be noted that in systems that do not have independent solenoids for brake activation and bridge/exhaust main event collapse a hydraulic element can be added to the system to create a delay between oil supply to the brake rocker and exhaust valve deactivation. In an exemplary embodiment, this hydraulic element could be an orifice to restrict flow to the bridge collapse circuit. In a slight variation, there is provided a shuttle valve between the brake and bridge circuit that is spring loaded to supply oil to the brake circuit first.

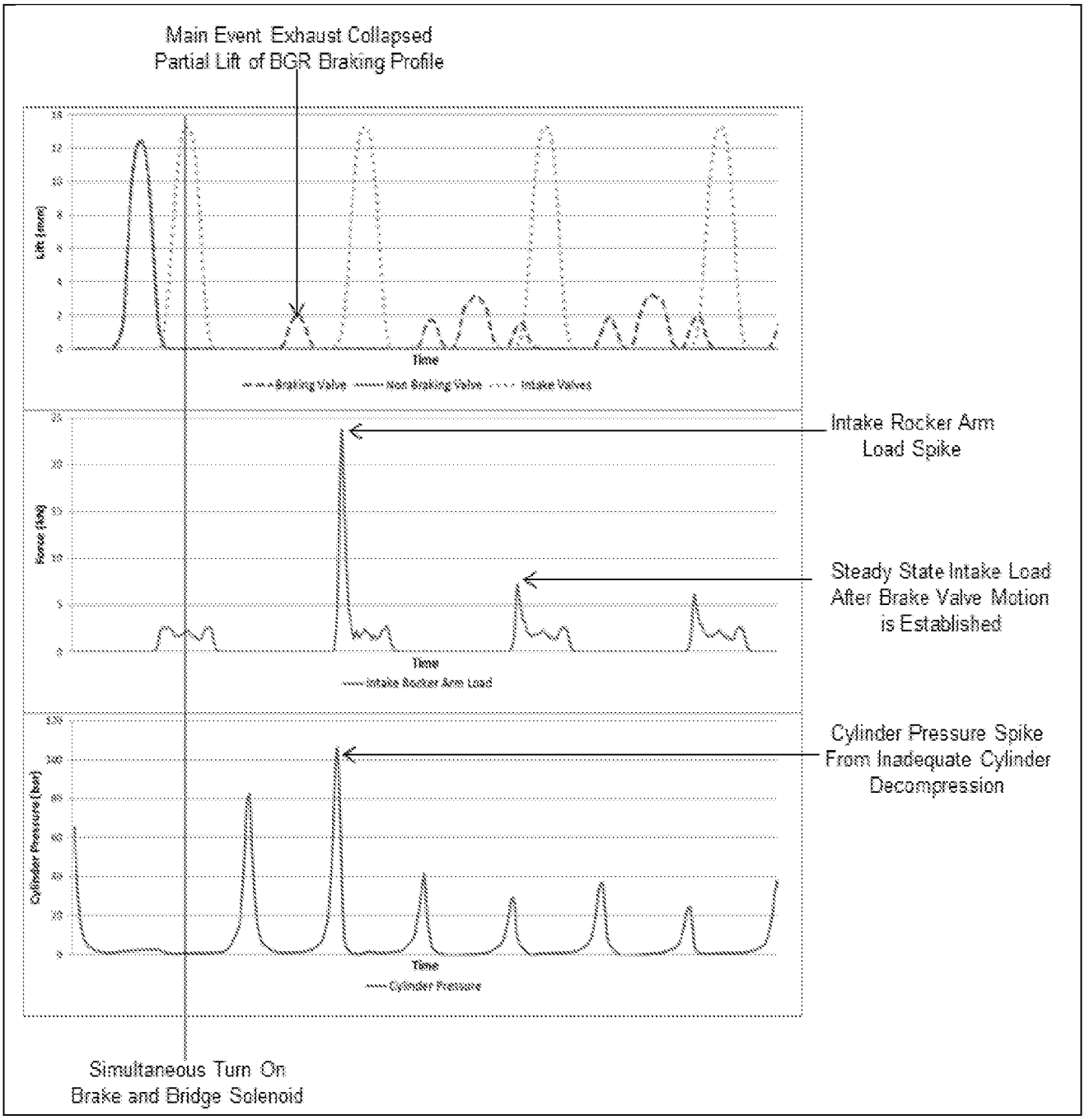
Main Event Exhaust Collapsed
Partial Lift of BGR Braking Profile
Intake Rocker Arm
Load Spike
Steady State Intake Load
After Brake Valve Motion
is Established
Cylinder Pressure Spike
From Inadequate Cylinder
Decompression
Simultaneous Turn On
Brake and Bridge Solenoid

FIG. 1

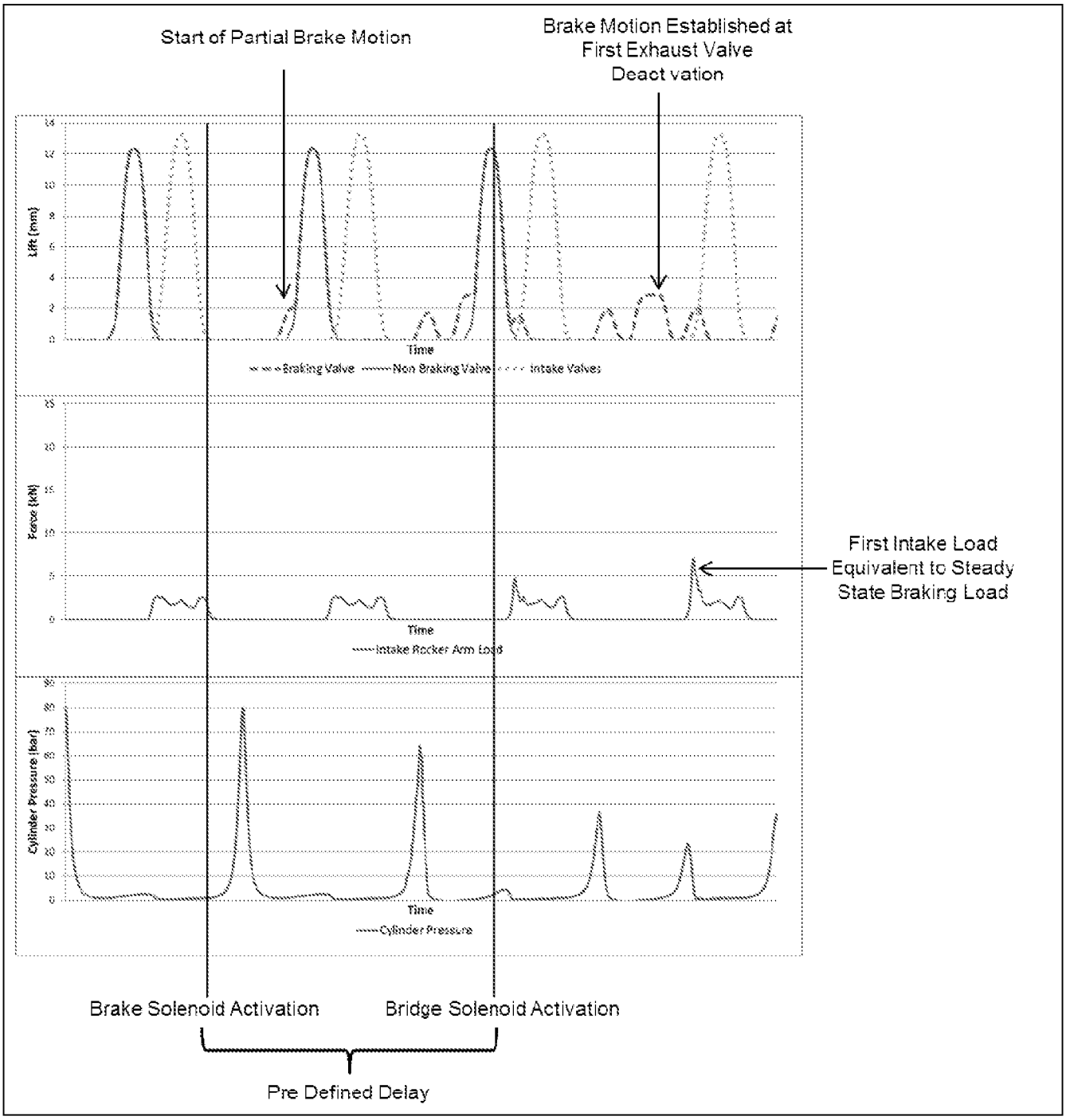
Start of Partial Brake Motion
Brake Motion Established at First Exhaust Valve Deact vation
Lift (mm)
Time
Braking Valve
Non Braking Valve
Intake Valves
Force (kN)
Time
Intake Rocker Arm Load
First Intake Load Equivalent to Steady State Braking Load
Cylinder Pressure (bar)
Time
Cylinder Pressure
Brake Solenoid Activation
Bridge Solenoid Activation
Pre Defined Delay

FIG. 2

Doc Code: **TR.PROV**
Document Description: Provisional Cover Sheet (SB16)

PTO/SB/16 (11-08)
Approved for use through 05/31/2015. OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

Inventor 1 — Remove

Given Name	Middle Name	Family Name	City	State	Country
Ryan		Lilly	Manchester	CT	US

Inventor 2 — Remove

Given Name	Middle Name	Family Name	City	State	Country
Matei		Alexandru	Somers	CT	US

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Title of Invention	METHOD FOR CONTROLLING INTAKE COUNTER FLOW SEEN DURING HPD TRANSIENT
Attorney Docket Number (if applicable)	JVS-ICFHPD

Correspondence Address

Direct all correspondence to (select one):

◉ The address corresponding to Customer Number	○ Firm or Individual Name
Customer Number	137097

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

◉ No.

○ Yes, the name of the U.S. Government agency and the Government contract number are:

Doc Code: **TR.PROV**
Document Description: Provisional Cover Sheet (SB16)

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Approved for use through 05/31/2015. OMB 0651-0032
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Entity Status

Applicant claims small entity status under 37 CFR 1.27

- ◯ Yes, applicant qualifies for small entity status under 37 CFR 1.27
- ◉ No

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Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Romi Bose/			Date (YYYY-MM-DD)	2017-08-03
First Name	Romi	Last Name	Bose	Registration Number (If appropriate)	43322

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Electronic Acknowledgement Receipt

EFS ID:	29975633
Application Number:	62540763
International Application Number:	
Confirmation Number:	5299
Title of Invention:	METHOD FOR CONTROLLING INTAKE COUNTER FLOW SEEN DURING HPD TRANSIENT
First Named Inventor/Applicant Name:	Ryan Lilly
Customer Number:	137097
Filer:	Romi Nilanjan Bose
Filer Authorized By:	
Attorney Docket Number:	JVS-ICFHPD
Receipt Date:	03-AUG-2017
Filing Date:	
Time Stamp:	14:47:35
Application Type:	Provisional

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		IntakeCounterFlow_fnl.pdf	395566 4f6e3bf00b821ccb7cba228a8867fe519ca3ab4a	yes	6

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Specification	1	4
	Drawings-other than black and white line drawings	5	6

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Information:					
2	Provisional Cover Sheet (SB16)	ProvisionalSB.pdf	2071586 f69c8ec0f0fe2cee8c33b7f68aec90b0a76fe65e	no	3
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	29704 da3701156560051672 6ca57c3d6d78c218a3c219	no	2
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EFS ID:	29980068
Application Number:	62540763
International Application Number:	
Confirmation Number:	5299
Title of Invention:	METHOD FOR CONTROLLING INTAKE COUNTER FLOW SEEN DURING HPD TRANSIENT
First Named Inventor/Applicant Name:	Ryan Lilly
Customer Number:	137097
Filer:	Romi Nilanjan Bose
Filer Authorized By:	
Attorney Docket Number:	JVS-ICFHPD
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Filing Date:	
Time Stamp:	17:42:19
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Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$260
RAM confirmation Number	080417INTEFSW17440100
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File Listing:

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1	Fee Worksheet (SB06)	fee-info.pdf	30007 b69f0f7057ee9e2bc5fe4fc29d28c25d67d5d473	no	2
Warnings:					
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