TECHNICAL SAFETY BC

Incident Summary #II-1447197-2022 (#30043) (FINAL)

SUPPORTING INFORMATION	Incident Date			October 3, 2022
	Location			New Westminster
	Regulated industry sector			Elevating devices - Elevator
	Impact	Injury	Qty injuries	0
			Injury description	None
			Injury rating	None
		Damage	Damage description	Burn damage to the elevator braking resistor bank, wires, toggle switches, and metal enclosure. Extended downtime for one of the two elevators.
			Damage rating	Moderate
	Incident rating			Moderate
	Incident overview			An elevator braking resistor bank overheated when exposed to continuous power related to a motor control drive transistor failure.
INVESTIGATION CONCLUSIONS	Site, system and components			The site is a 14-floor high rise apartment building with two separate passenger elevators of the electric traction type. The elevator power equipment, motors, drives, and resistor banks are located in the upper floor elevator machine room. Each elevator motor has a controller cabinet (Image 1) which houses a variable frequency drive (VFD) and the braking resistor components. The VFD takes the 480-volt alternating current (AC) power supply and inverts it to roughly 680-volts direct current (DC) with capacitive power smoothing on the DC bus. The VFD then uses pulse width modulation (PWM) (Image 10) to adjust the frequency and amplitude of the output power to the elevator motor (Image 2). For PWM, the drive employs 6 insulated gate bipolar transistors (IGBT's) to switch on and off the power up to 16,000 times per second to create variable frequency, variable voltage power for smooth speed control of the 3-phase elevator motor. A braking resistor bank is used to dissipate excess energy as heat from the VFD's DC bus. The excess energy can be created when the elevator motor acts like a generator during periods of full load going down (deceleration) or no load going up (overdrive). A seventh IGBT (Image 9) turns on and off rapidly between 1,000 to 4,000 cycles per second (1-4KHz) when the DC voltage exceeds the drive's default threshold of 760-volts DC. The transistor directs the excess energy to the resistor bank to dissipate as heat. Dissipating the heat energy to the braking resistors protects the VFD components such as the DC bus, transistors, and capacitors. The resistors in the bank are sized for intermittent use with the transistor and not for continuous connection to the DC Bus. Proper sizing of the resistor bank is critical to protect the DC bus components and to prevent the resistor from overheating. A transistor is a solid-state component that can switch on and off power circuits such as the resistor banks from a lower power control circuit. The low power circuit uses electronic components such as microchips to provide rapid switching of the

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	transistor. Heat sinks connected to the transistor provide a larger metal surface to dissipate heat created by transistors. Temperature sensors and thermostatically controlled fans assist in cooling the heat sink and transistors.
Failure scenario(s)	Both elevators in the building were retrofitted during a modernization project in 2017/2018. The upgrade included new VFD's and braking resistor banks. The VFD's had a transistor intended to limit power to the braking resistors by switching on and off rapidly. The transistor experienced an internal failure in one of the VFD's that resulted in continuous power rather than switching on and off as intended. With the failed transistor in a continuous state, it no longer limited power and the resistor bank overheated (Image 5) from the excess power. Occupants smelled smoke and heard the fire alarms go off at the time of the incident.

Facts and evidence	**TSBC investigator site findings**
	• Elevator controller #1 had fire damage to the resistors, controller cabinet paint, rubber isolation pads, capacitor, wires, and toggle switches.
	• Based on the specifics of the part number, the VFD was not issued with a monitoring circuit for the braking resistors (Image 2).
	• The heat sink and fan for the braking transistor were in place (Image 11 & Image 12). There was no evidence that they were not operating effectively to cool the transistor.
	
	VFD testing by independent contractor (Refer to Appendix A for full report)
	• Testing was performed on site on the unpowered VFD with a digital multimeter in the diode setting.
	• The testing used a process outlined to ensure the function of the transistors in the manufacturer's installation manual.
	• Resistance levels of the braking transistor were outside the ranges specified in the manual. This indicated the transistor had experienced a failure (Image 8).
	• The transistors that control the motor had resistance levels within the ranges specified in the manual.
	
	Drive manufacturer statements
	• The source of the resistor bank overheating was identified as a faulty brake transistor manufactured by IXYS Corporation with part number VUB120-16NOX.
	• After the drive manufacturer performed internal quality analysis and external third-party review of the damaged modules, it was concluded that the individual IGBT cells which make up the IGBT chip were breaking down.
	  – X-ray review of new units displayed microscopic air pockets in some units, resulting in inadequate heat transfer and thereby failure of the cell.
	  – When cells begin to fail this creates an avalanche affect and eventually burns a hole in the IGBT chip creating a short.
	  – The failures typically occurred within one to two years of the drive production date, which is generally six months to a year from commissioning of the elevator.
	• In response to the analysis, new "G" housing frame drives in production were redesigned and thereafter built with brake transistor and power modules from another manufacturer.

- The previous model of the "G" housing frame drive was discontinued and replaced with this redesigned drive.
- All "G" housing frame drives produced from 2021 onward contained new components to eliminate the previous issues, and additionally an internal brake transistor monitor.
- The model numbers of the KEB drives are addressed in the KEB bulletins dated December 27th, 2019, (Image 14) and November 16th, 2021, (Image 15) and are 16F5A1G-RPxx, 16F5A1G-RLxx, 17F5A1G-RPxx, 17F5A1G-RLxx, where "xx" can be any combination of two letters and/or numbers. The production years affected by this are 2016 through 2019.
- KEB has always included a statement in its instruction manual which informs direct and end customers about the need to provide thermal protection for the braking resistor (Image 13).
- As the brake transistor failure problem became more apparent and KEB realized that, for the most part, the thermal protection devices were not being installed by installers, it was decided to expand the safety circuit protection options for the braking transistor in the instruction manual.
- There were 16 documented returns from the field of the KEB F5 "G" housing frame drive with a failed braking transistor IGBT.
- The KEB warranty applies to "G" housing frame drives that experience a failure of either the Infineon motor power module or the IXYS braking transistor within 5 years of the manufacturer date.
- Currently, the elevator safety standard CSA B44.1/ASME A17.5 does not include any specific requirement to address the protection of the braking resistors.

Controller manufacturer statements

Equipment description

- There are seven IGBT's in the VFD that are the same type and from the same vendor. Six are used for the motor output and one is used for the dynamic braking resistors (DBR's).
- The seventh IGBT on the drive engages the DBR's when the nominal DC bus voltage of the drive exceeds 760 VDC on a 480V drive. The switching frequency of the IGBT varies from 1 to 4K Hz [1,000 – 4,000 cycles per second].
- The DBR is a self-regulating circuit in that there are no parameter adjustments on when and how the current flows. The amount of power involved at any given time is the voltage squared divided by the DBR's resistance (V^2R).
- The IGBT's are not undersized, they are well within size range for this site.
- The resistors and other related components are not undersized for this site.
- The DBR is sized for each site by the controller manufacturer.

Failure description

- An IGBT can fail in two ways, open or close. If the IGBT opens, the drive will fault on an over potential fault but no further harm than a shutdown until the drive is replaced or repaired.
- However, in the scope of this failure, the IGBT failed to a closed state, which created a continuous current path from the line voltage to the DC bus and then to the DBRs. There is no mechanical way to remedy this condition other than physically disconnecting the power source to the drive or until a component finally fails to an open state (e.g., wire melts creating a break in the circuit).

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	• Through several internal failure analyses by the drive manufacturer, it was determined that the IGBTs were problematic. They switched their supplier as a result. • Provided serial and model number information that can easily identify which power device supplier was used in a drive. The IGBT that is used to switch power on and off to dissipate power to the resistors can become shorted and a continuous path. • The IGBT's that fail were produced by a particular vendor on a particular run. • Since the manufacturer has switched to another IGBT, the controller manufacturer has not seen this issue. **Technical bulletin 157 (TB 157)** • The bulletin was written to address a special product reliability concern on the G housing drive during a specific production run. • The bulletin applies to drives within the serial number range. • TB 157 was sent to the controller manufacturer's customer base through an email distribution list including direct customers and some consultants that subscribe. • The bookends of the affected timeframe are laid out in TB 157. During that time, the drive manufacturer saw an unusually high amount of drive failures that were still deemed recently installed (2-4 years). • TB # 157 allowed for an exchange of drive with a new drive that addresses all 7 of the IGBTs. • The IGBT's that cause the failure were only in the G housing during the time period [In TB # 157]. • In the last year (roughly) the controller manufacturer has only been issuing drives from this drive manufacturer that include the DBR monitoring circuit to clients. It is then up to the elevator integrator company if they choose to use that monitoring circuit or not. • The monitoring circuit disengages when the elevator comes to a stop to allow passengers to exit. • These failures have caused the controller manufacturer to re-evaluate whether to have a secondary monitoring device regardless of which housing and which drive manufacturer is used. • Warranty claims submitted to the controller manufacturer have been limited to the production run of the G housing within the period when the manufacturer used that suspected [IGBT] supplier.
Causes and contributing factors	The cause of the incident was the transistor failing internally, during normal operating conditions, allowing continuous current to overheat the braking resistor bank until the fire occurred. The incident most likely would have been prevented if a thermal monitoring circuit was installed and operating for the elevator controller.

Image 1 – Elevator controller

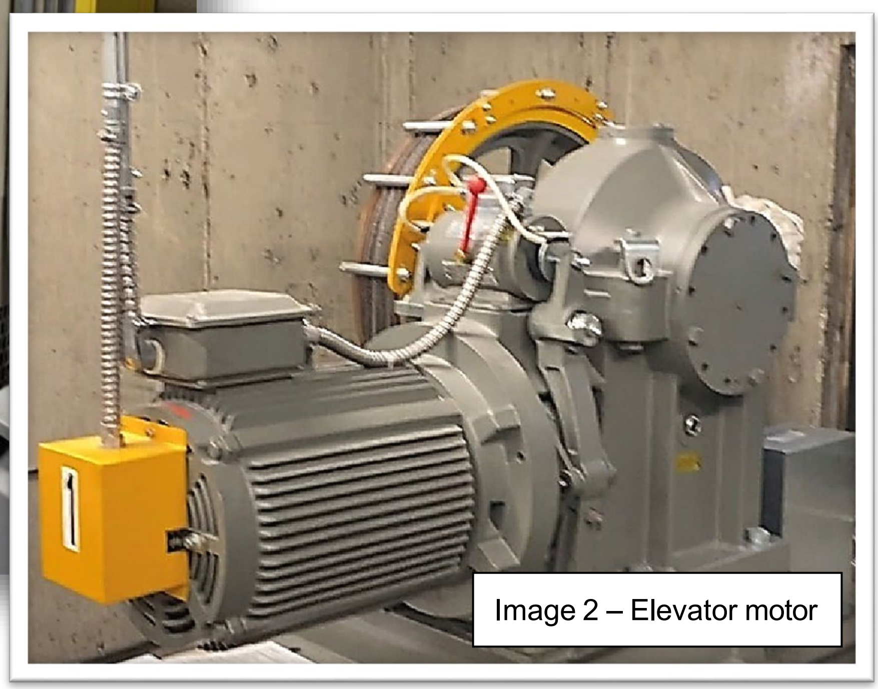


Image 2 – Elevator motor

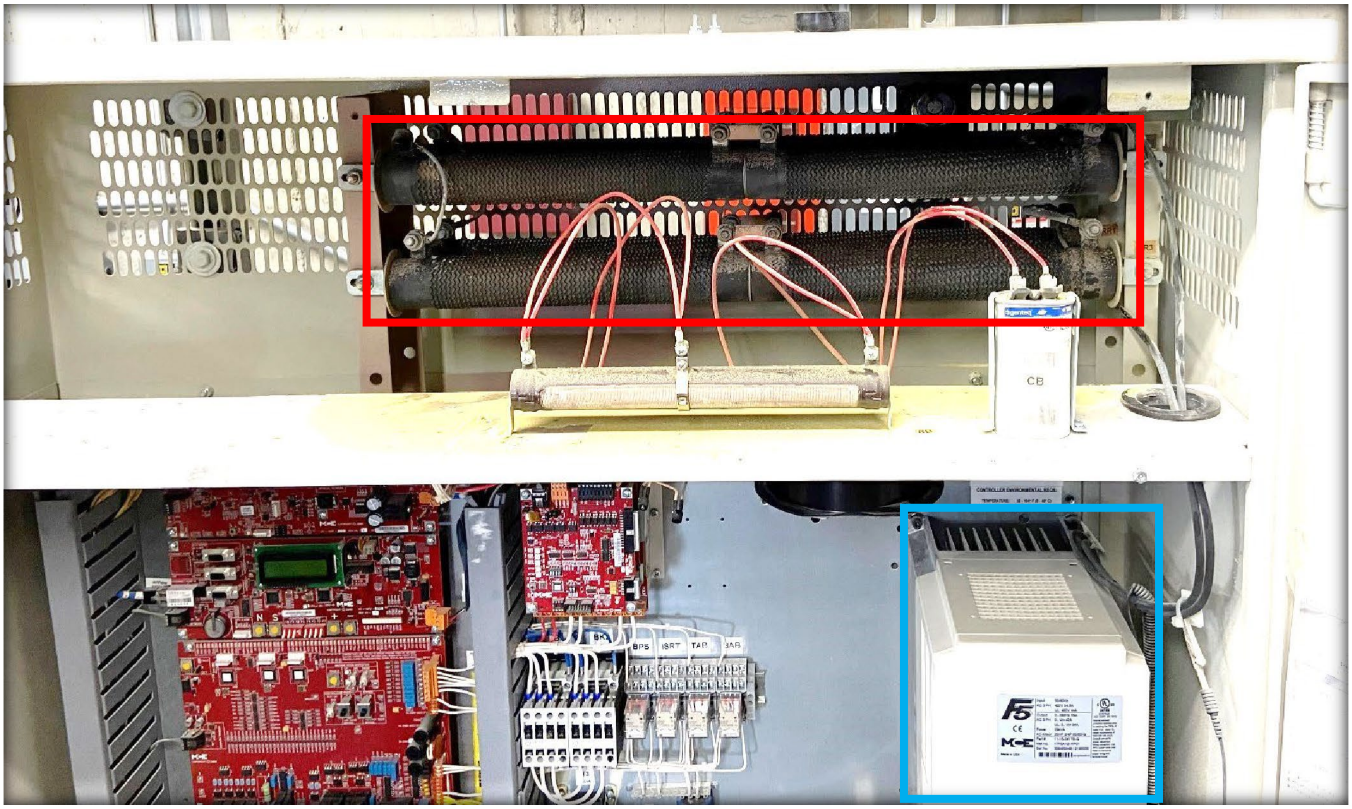
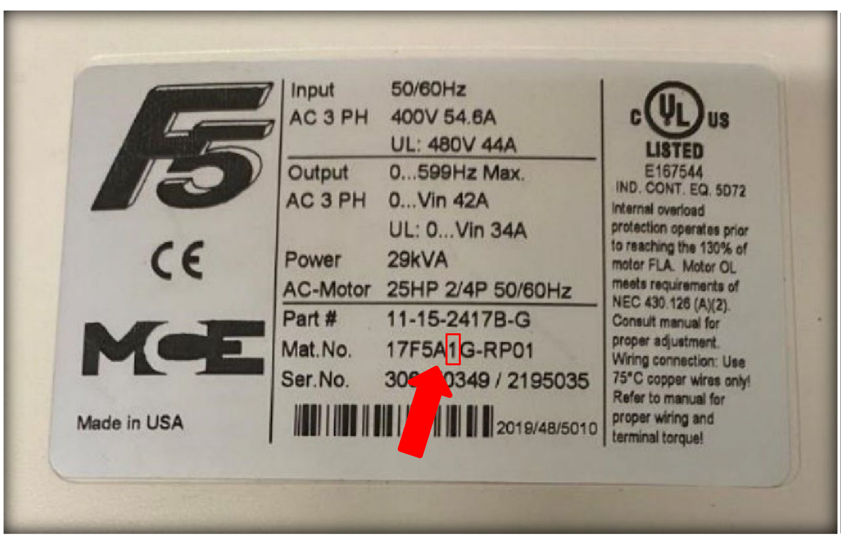


Image 3 – Elevator controller including fire damaged resistor bank (Red rectangle), VFD (blue square).



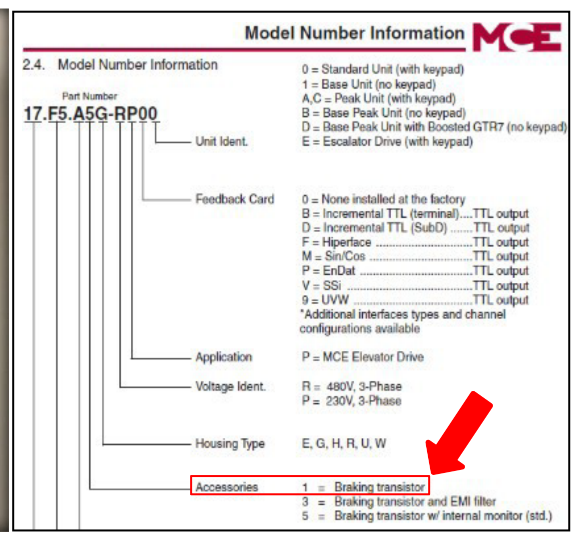


Image 4 – VFD label with braking transistor only indicated in part number, no internal monitor.

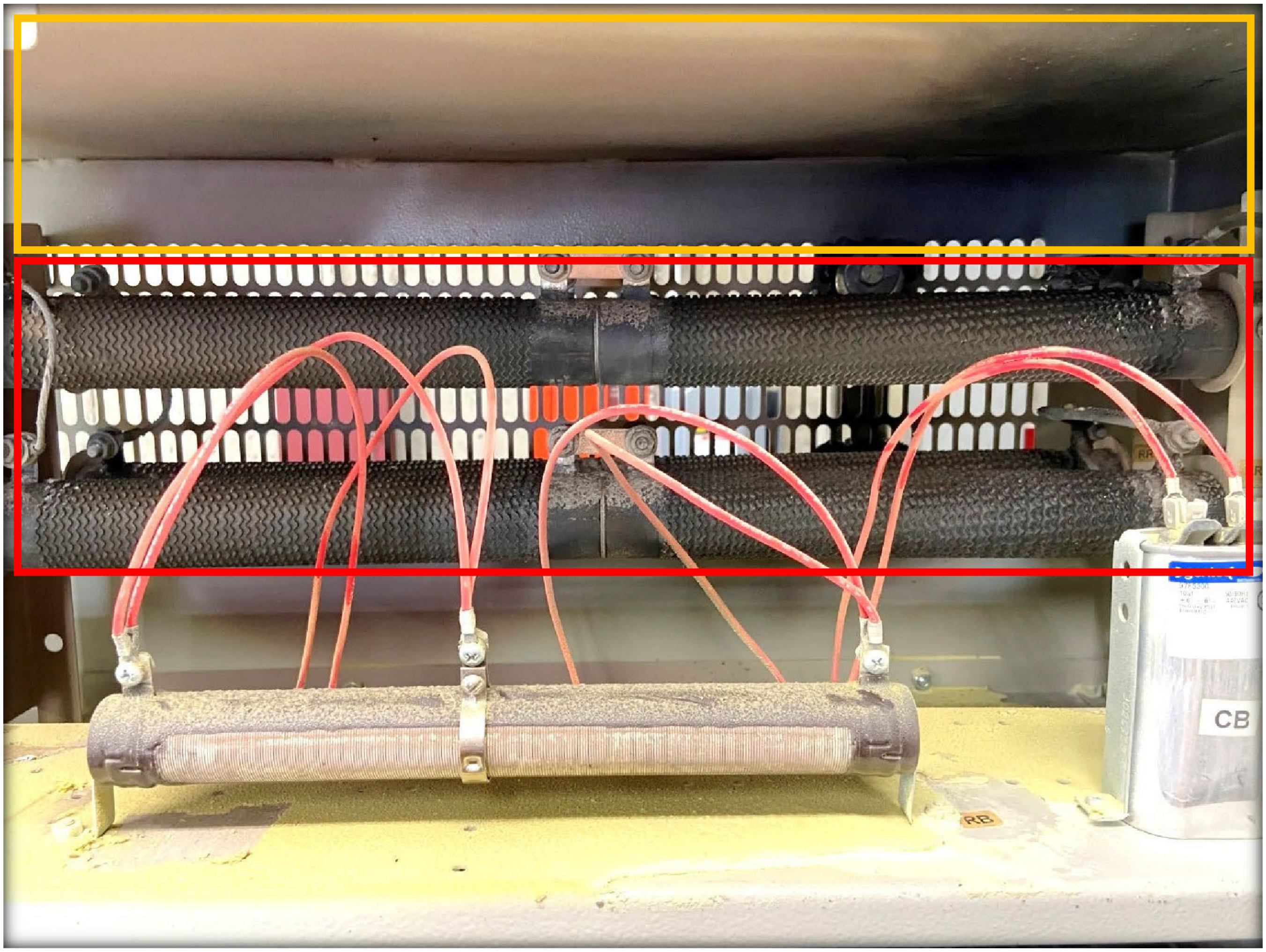


Image 5 – Resistor bank (red), fire damage (orange), yellow dry chemical fire extinguishing substance.

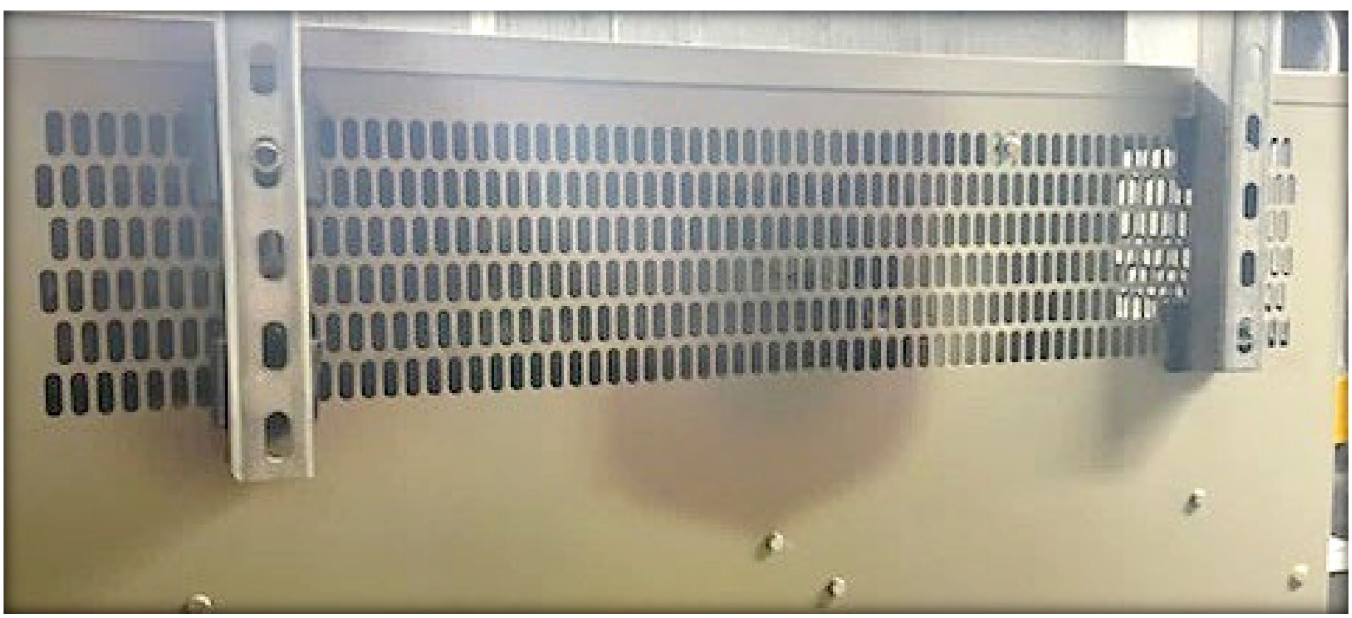


Image 6 – Heat damage to the back of the elevator controller cabinet.

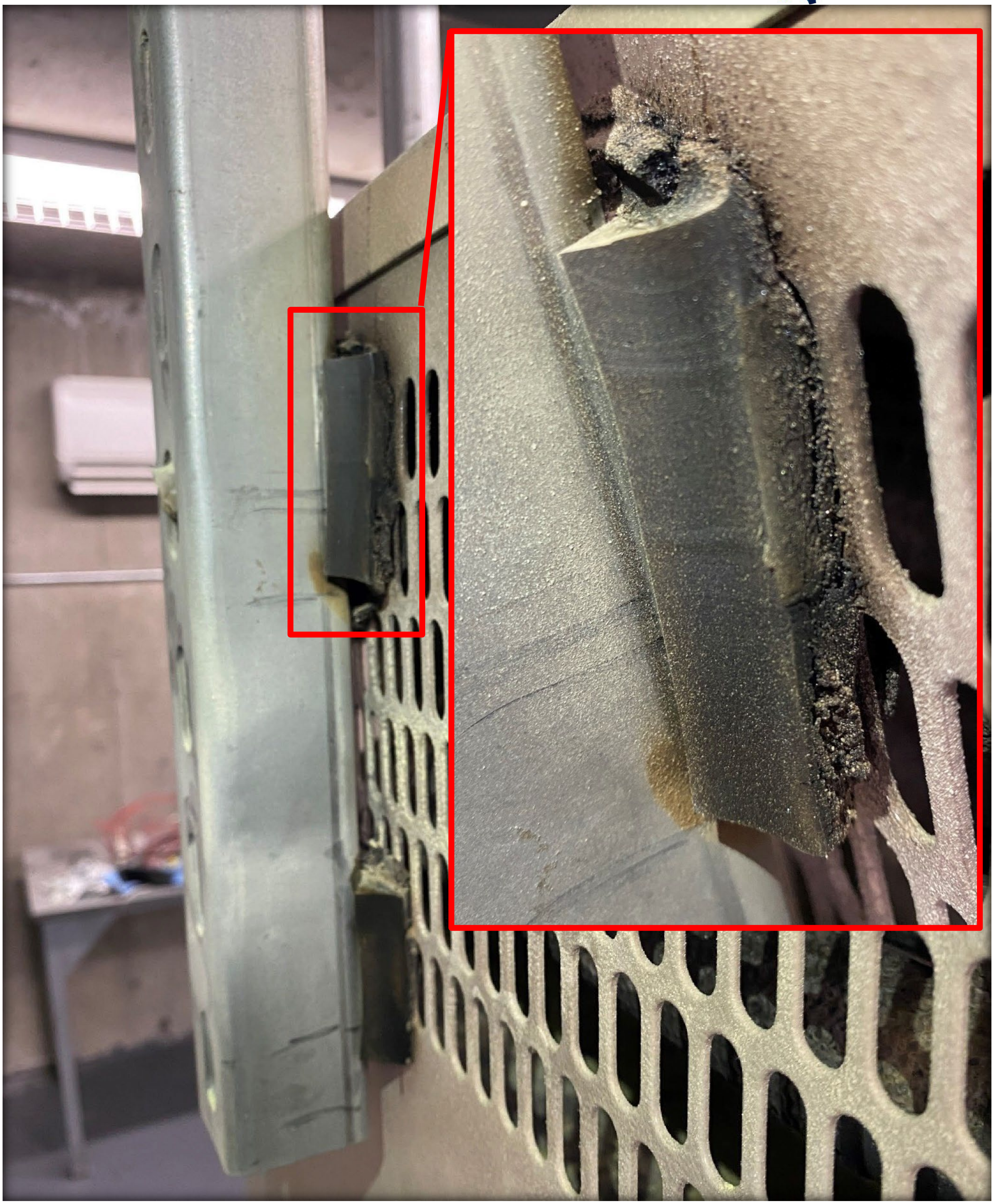
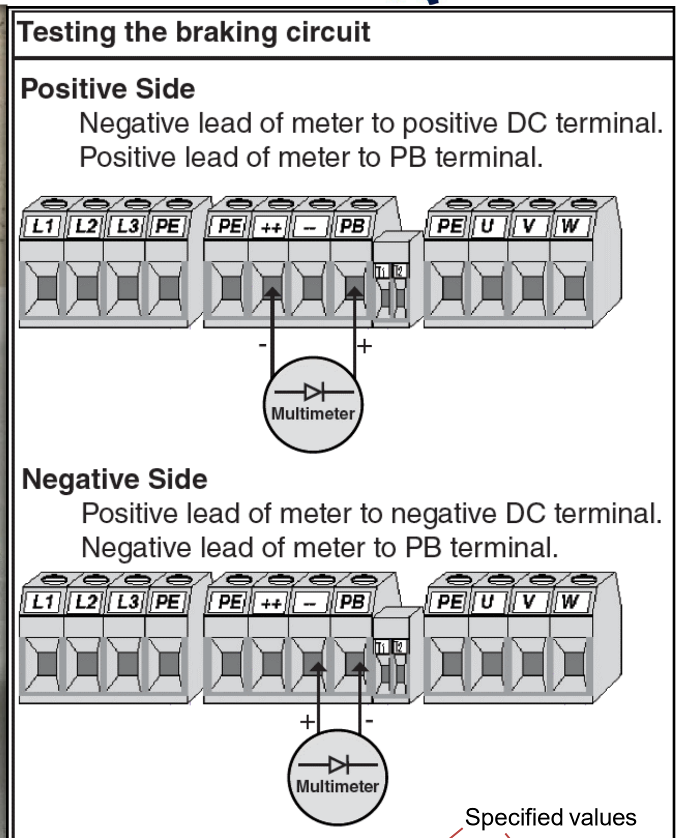


Image 7 – Heat damage to rubber insulators on back of elevator cabinet with close-up of insulator.



G Housing					
Measurement	To	Value	Measurement	To	Value
+ Terminal	PB	0.4	- Terminal	PB	1.5

Image 8 – Testing results out of range from the "G" housing specification of 1.5 VDC at **-0.008 to -0.009 VDC.** The measurement taken from the negative terminal to the PB terminal for the braking circuit indicates the braking transistor had failed.

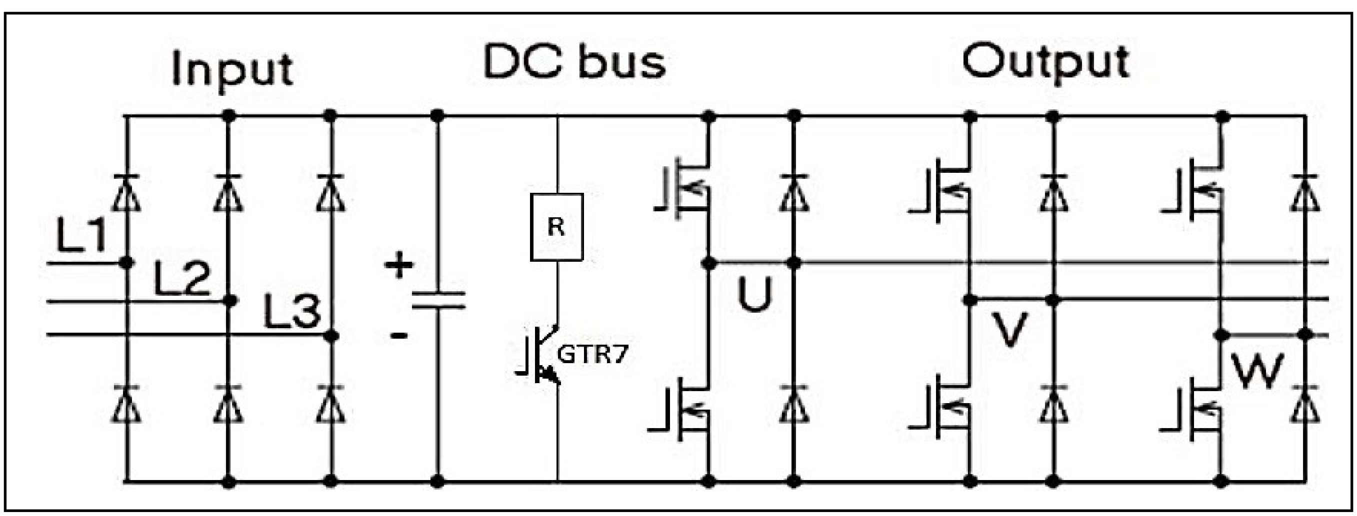


Image 9 – VFD single line diagram. R label is the resistor bank, GTR7 label is the braking transistor.

https://www.kebamerica.com/wp-content/uploads/2021/05/MCE-v3.33-LCD-Rev1B.pdf

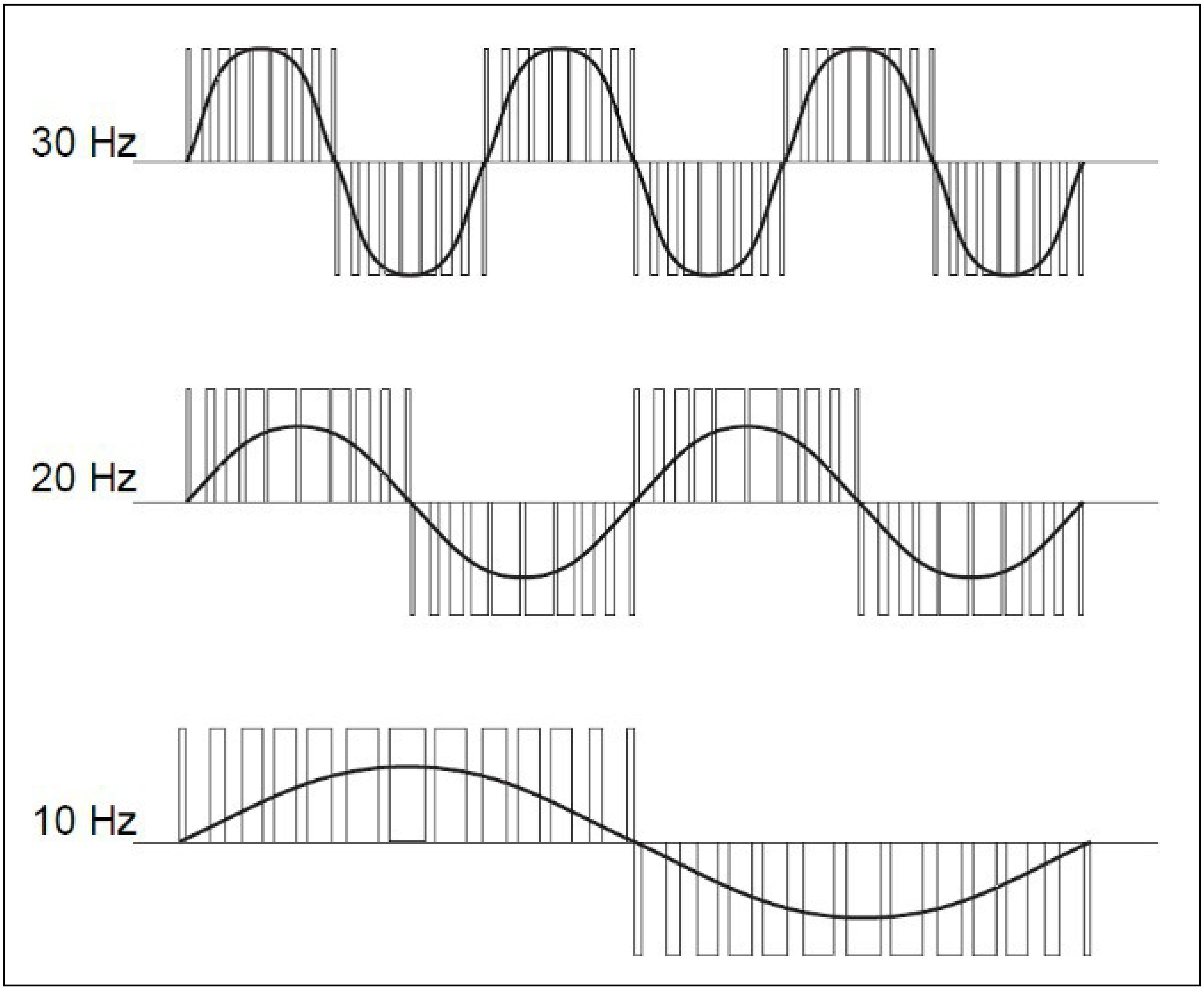


Image 10 – VFD controlled sine waveform examples.
https://kebamerica.com/wp-content/uploads/2020/02/pwm-for-different-output-frequencies.png

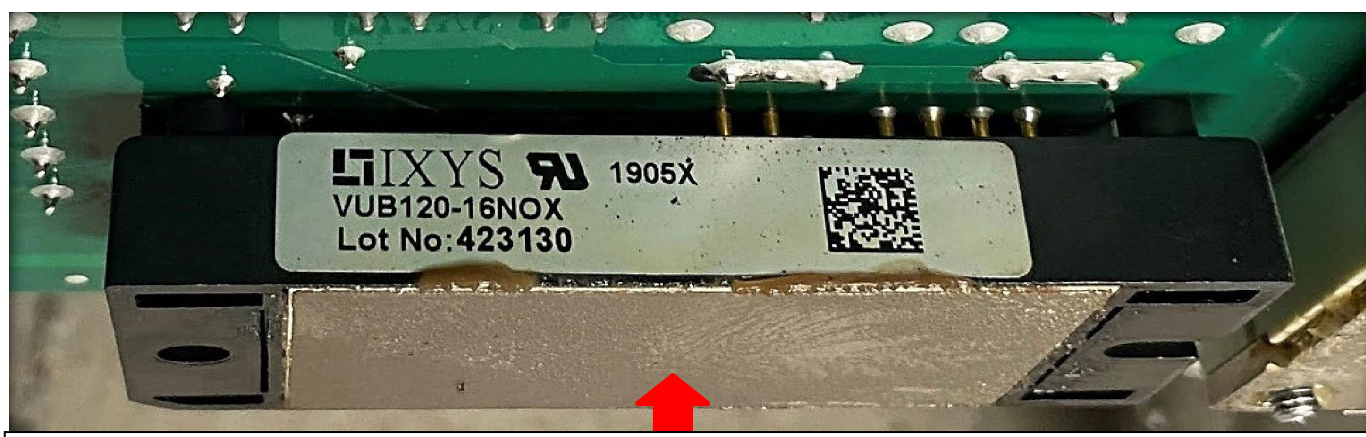


Image 11 – Braking transistor pack, heat sink used for transistor cooling attaches to the metal plate (red arrow).

Image 12 – Heat sink with integral fan under cover to cool transistor pack.

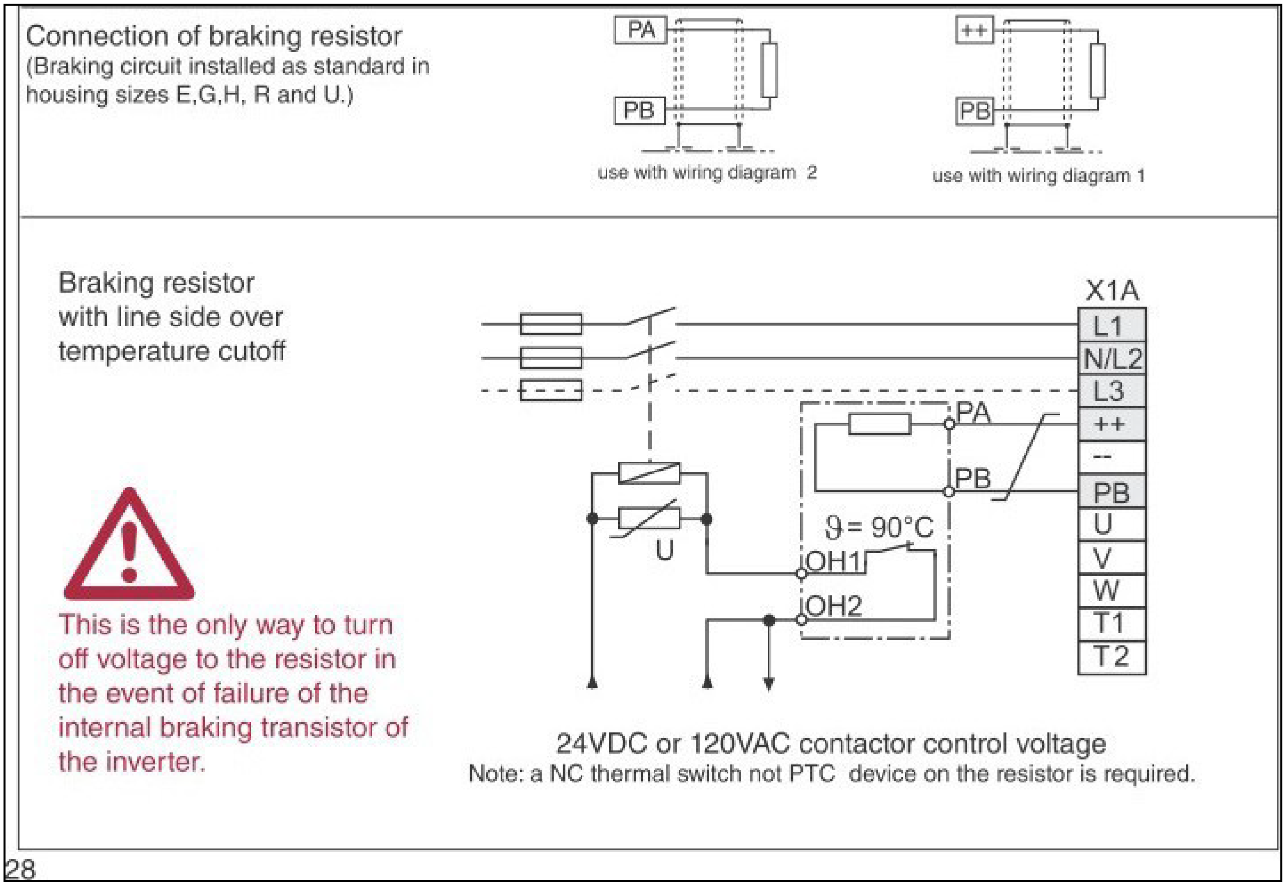


Image 13 – Excerpt of KEB instruction manual, circa 2016 timeframe, regarding thermal protection of braking resistors.

KEB PRODUCT BULLETIN

To: KEB Customers
From: KEB America, Inc.
Date: December 27, 2019
Subject: F5 Component Supplier Problem

Equipment Affected: 480V size 16 and 17 F5 G Housing Drives

Description: KEB has identified a problem with a component supplier that can cause the F5 drive to fail prematurely. Modes of failure include a shorted braking transistor or the drive can trigger an "Error Over Current" (E.OC) fault.

KEB is working with our supplier to identify and fix the root cause of the problem. However, until a solution is identified and thoroughly tested, KEB is temporarily halting sale of the affected units. Affected units include only the 480V F5 G housings, with the following part numbers from production years 2016 to 2019.

16F5A1G-RP00
16F5A1G-RP01

17F5A1G-RP00
17F5A1G-RP01

KEB will warranty all affected units and is asking customers to transition to the size 16 and 17 480V F5 H housings as a temporary solution. As we review the status of the ongoing investigation with our supplier, we will provide a status update to our customers every 90 days. Serial numbers will be used to track and identify affected failed units needing field replacement. The following part numbers will be used for new installation and field replacements.

16F5A1G-RP00 and 16F5A1G-RP01 will be replaced by 16F5A1H-RP01

17F5A1G-RP00 and 17F5A1G-RP01 will be replaced by 17F5A1H-RP01

Further Help: For further assistance, please call the KEB mainline (952-224-1400) and ask for Elevator Tech Support.

Image 14 – KEB 2019 Product bulletin

SALES INFO AUTOMATION & DRIVES KEB

No. US002/2021

Product:	**480V size 16 and 17 F5 G Housing Drives**	**From:**	Production years 2016-2019
Subject:	F5 Component Supplier Problem	**To:**	☒ Customers ☐ Sales ☐ Engineering ☐ Service
		Page:	1 / 1
		Date:	November 22, 2021

Ladies and Gentlemen,

KEB has identified a problem with a component supplier that can cause the F5 drive power modules to fail prematurely. Modes of failure include a shorted braking transistor or the drive can trigger an "Error Over Current" (E.OC) fault. Affected units include only the 480V F5 G housings, with the following part numbers from production years 2016 to 2019.

16F5A1G-RL++
17F5A1G-RL++

++ is a generic placeholder denoting different keypad/encoder card configurations.

KEB will warranty units that have failed 5 years from the unit production year (production years 2016 - 2019).

Sincerely,

KEB America Inc.

Image 15 – KEB 2021 communication