Technical Report

Industry-wide Misunderstandings of HTTPS

70% of sites tested expose private data on users' machines

Independent Security Evaluators | www.securityevaluators.com

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Abstract

Most web browsers, historically, were cautious about caching content delivered over an HTTPS connection to disk—to a greater degree than required by the HTTP standard. In recent years, in response to the increased use of HTTPS for non-sensitive data, and the proliferation of bandwidth-hungry AJAX and Web 2.0 sites, some browsers have been changed to strictly follow the standard, and cache HTTPS content far more aggressively than before. HTTPS web servers must explicitly include a response header to block standards-compliant browsers from caching the response to disk—and not all web developers have caught up to the new browser behavior. ISE identified 21 (70% of sites tested) financial, healthcare, insurance and utility account sites that failed to forbid browsers from storing cached content on disk, and as a result, after visiting these sites, unencrypted sensitive content is left behind on end-users' machines.

Overview

Users often visit the same web pages more than once, such as checking a news site every day. While some of the page contents may change often, the vast majority of the page and associated resources (such as images) never change. To re-download this unchanged content on every visit of the page would be a waste of time and bandwidth. To avoid this, when a user accesses a web page, the web browser caches (saves a copy of) most content locally on the user's machine. This content can either be saved in temporary memory (RAM), which is lost as soon as the user exits the browser, or on disk, which persists after the user exits the browser or reboots the computer. When a user visits a previous page a second time, the content is retrieved from cache instead of over the Internet. Memory caches are lost when the browser exits, so the browser uses the disk cache whenever possible.

Secure web sites use the HTTPS and SSL/TLS protocols to encrypt information as it travels over the Internet, to prevent an eavesdropper or man-in-the-middle from seeing or modifying the communication. Although there are no technical constraints preventing content sent over an encrypted connection from being decrypted and written to disk, it is logical to presume that if content is too sensitive to be sent over a network without encryption, then it may also be too sensitive to store unprotected on a hard drive. When HTTPS was first introduced, there was no standard, unambiguous way for a web server to mark content as too sensitive to store in cache. As a result, web browser authors created their own mechanisms for a web server to restrict disk caching [1]. Some browser authors chose to, by default, never write content transferred over HTTPS to disk [2], or did not disk cache content unless a server header explicitly allowed it ("opt-in") [3], while others chose to write this content to the disk cache, unless a server header explicitly prohibited it ("opt-out") [4].

In 1999, the HTTP/1.1 standard was published, which standardized the header [5] that a server must set to prevent content from being written to a disk cache. By that time, all web browser authors had already adopted either an opt-in HTTPS disk caching policy, or an opt-out policy with multiple, non-standard ways to opt out. Despite the new standard, web developers could continue to use the old, non-standard methods and they would continue to work only in the browsers that recognized them [1].

Between the release of Netscape Navigator 3.0 in 1996, and 2008, when Google Chrome was released, the only browser with a significant market share that used an "opt-out" HTTPS disk caching policy was Internet Explorer. Internet Explorer has always been very forgiving in determining a web server's intention that a response not be written to the disk cache.

INDUSTRY-WIDE MISUNDERSTANDINGS OF HTTPS

ISE identified four separate ways [1] that can a web developer can prevent a response from being cached to disk. Only one of those ways, the header Cache-Control: no-store, is actually standard [5].

Encrypted web servers (HTTPS) have higher overhead and lower performance than unencrypted servers due to the need to perform encryption, and in the past this overhead was much more pronounced. For this reason, many web sites used HTTPS only when absolutely necessary, such as for sending a password or credit card information. After the sensitive transaction was completed, the sites would switch back to an unencrypted connection. Two examples are Gmail, which transmitted e-mails over unencrypted connections until 2010 [6], and Facebook, which continued to use unencrypted connections until 2012 [7]. Since HTTPS was reserved for only the most sensitive information, an opt-in disk caching policy was a very reasonable design.

By 2011, many sites had begun using HTTPS even for non-sensitive content, and Mozilla Corporation recognized that the opt-in HTTPS disk caching policy in Firefox was introducing a performance penalty compared to other browsers, including Google Chrome, which uses an opt-out policy. As a result, Firefox 4.0 and all later versions use an opt-out HTTPS disk caching policy [8]. A Firefox 3.6 user would be unaffected by this issue, even when browsing HTTPS sites that fail to set the necessary header, but would become affected as soon as that user updated to Firefox 4 or later.

Online banking, which is among the most security-sensitive uses of a web browser, exploded in popularity in the early 2000s. This was a time when Internet Explorer had over 90% market share, and before Safari and Chrome even existed. Internet Explorer's only significant competitors at the time (Netscape 3.0 and later, Mozilla, and Firefox) either did not disk cache HTTPS content at all (unless a user manually modified a configuration parameter), or used an opt-in policy, and thus required no special treatment to prevent caching of encrypted bank pages. Many of the web sites that we tested responded with sufficient headers to prevent caching in all versions of Internet Explorer, all versions of Safari, and Firefox 3.6 and earlier, but not Firefox 4.0 and later, or any version of Chrome. We believe that ensuring that sensitive content is not cached on disk by the browser was a design goal in these web applications. While this anti-disk cache functionality worked correctly in the past, it no longer works in two of today's popular browsers: Chrome, and Firefox 4.0 and later. Since this has been an issue in Chrome since its release in 2008, and in Firefox since 2011, the maintainers of these sites do not appear to perform regression testing for this issue.

Today, Internet Explorer continues to follow the same HTTPS disk caching policy as it always has: enable disk caching by default, but allow four different ways to disable it. Google Chrome and Firefox, in contrast, enable disk caching by default, but allow only one way to prevent it—the one given in the standard, the header Cache-Control: no-store.

Google Chrome and Mozilla Firefox, together, now have over a 60% market share on non-mobile devices [9], but many web sites still use antiquated, non-standard methods to prevent disk caching of sensitive HTTPS content that only function in Internet Explorer.

Caching Policies by Browser

Disk caching of HTTPS-delivered web pages varies by web browser. Below are the policies of four browsers that we tested.

INTERNET EXPLORER

Microsoft Internet Explorer caches HTTPS-delivered content to disk, unless one or more of the following are present [1]:

- The HTTP header `Cache-Control: no-store`.
- The HTTP header `Cache-Control: no-cache`.
- The HTTP header `Pragma: no-cache`.
- The HTML tag `<META HTTP-EQUIV="Pragma" CONTENT="no-cache">`. Microsoft discourages the use of this method; it may not work properly for pages larger than 32 kilobytes [10].

Note that the Cache-Control header **cannot** be set using an HTML <META HTTP-EQUIV> tag. Additionally, Internet Explorer interprets some of these headers differently, depending upon whether the page was delievered using HTTPS or HTTP.

ISE verified that this behavior as described using the 32-bit version of Internet Explorer 10.0.9200.16576 on 64-bit Windows 7.

FIREFOX

Prior to version 4.0, Mozilla Firefox (and its predecessors, including Mozilla and Netscape) either *never* cache HTTPS pages to disk at all, or cache only pages sent with:

- The HTTP header `Cache-Control: public`.

Firefox contains a hidden browser preference, `browser.cache.disk_cache_ssl`, that when set to `true`, switches Firefox from the previous, cautious policy above, to a new policy that strictly follows the HTTP standard, disk caching all content unless specifically instructed not to do so by the server. In 2011, the default value of this preference was switched from `false` to `true` [8]. As a result, Firefox 4.0 and all later versions cache HTTPS-delivered content to disk, unless the following is present:

- The HTTP header `Cache-Control: no-store`.

ISE verified that using the 32-bit version of Mozilla Firefox 3.6.28 on 64-bit Windows 7 (and earlier), HTTPS content is not disk cached unless the server sends the `Cache-Control: public` header. ISE verified that using the 32-bit version of Mozilla Firefox 21.0 on 64-bit Windows 7, Mozilla Firefox 21.0 on Mac OS X 10.7.5, and Mozilla Firefox 21.0 on Android 2.3.6, HTTPS content is disk cached unless the server sends the `Cache-Control: no-store` header.

CHROME

Google Chrome caches HTTPS-delivered content to disk, unless the following is present:

- The HTTP header `Cache-Control: no-store`.

ISE verified that using Google Chrome 27.0.1453.94m on Windows 7, and the Browser app in Android 2.3.6 (which is based on Chrome), HTTPS content is disk cached unless the server sends the `Cache-Control: no-store` header.

SAFARI

Apple Safari does **not** cache HTTPS-delivered content to disk, regardless of any headers sent by the server. ISE tested the mobile version of Safari on an iPad 2, and the HTTPS caching behavior was identical to the desktop version.

ISE verified that using Safari 6.0 (7536.25) on Mac OS X 10.7.5, and Mobile Safari on iOS 5.1.1, HTTPS content is never disk cached.

A word about private browsing modes. Virtually all web browsers now include a "private browsing" mode, that in addition to preventing browsing history from being retained, disables the disk cache entirely. While sufficient for a user to avoid this issue, we do not consider advising users to use private browsing to be a reasonable solution for several reasons. First, private browsing modes are not the default, and must manually be enabled by a user. Second, other aspects of private browsing, such as not retaining persistent cookies, break useful functionality in web sites, such as remembering usernames or remembering the computer to avoid answering security questions on each login. Third, since private browsing disables the disk cache entirely, it has negative side effects on the performance of the Internet as a whole, since even unencrypted HTTP content must be re-downloaded if the browser has been closed.

Site Survey

Methodology

ISE tested thirty secure, password-protected sites that displayed sensitive personal information in a web browser. This involved accessing SSL-protected websites as an authorized user, logging out of the site, and closing the Firefox browser. Then, ISE reopened the browser, placed it in offline mode, and checked the disk cache for entries containing sensitive data.

Initial Results

As of April 25, 2013, twenty-one of the thirty sites tested were not sending the `Cache-Control: no-store` header required by the HTTPS standard to prevent disk caching of sensitive data. Some were not sending any caching-related headers at all, while others were sending caching headers that prevent disk caching only in Internet Explorer, or other headers not relevant to web browser caches.

The following sites sent sensitive information with both of the headers Cache-Control: no-cache, and Pragma: no-cache, which prevent disk caching in Internet Explorer, but not Firefox or Chrome:

ADP	Full earnings statements, including names, addresses, the last four digits of the employee's social security number, and financial data
BGE	Customer names, addresses, account numbers, and balances
M & T BANK WEALTHCARE	Customer names, account numbers, and balances
SCOTTRADE	Account numbers and balances
TREASURYDIRECT	Customer names, the last four digits of the account holder's social security number, addresses, and telephone numbers
VERIZON WIRELESS	Call details

The following sites sent sensitive information with the header `Cache-Control: no-cache` which prevents disk caching in Internet Explorer, but not Firefox or Chrome:

BB&T	Customer names, email addresses, the last four digits of account numbers, and account balances
LIBERTY MUTUAL	Customer names, policy numbers, property addresses, and policy limits
PAYPAL	Customer names, email addresses, addresses, and phone numbers

The following sites sent sensitive information with the header `Cache-Control: private`, which has no effect on whether or not a web browser caches the information to disk:

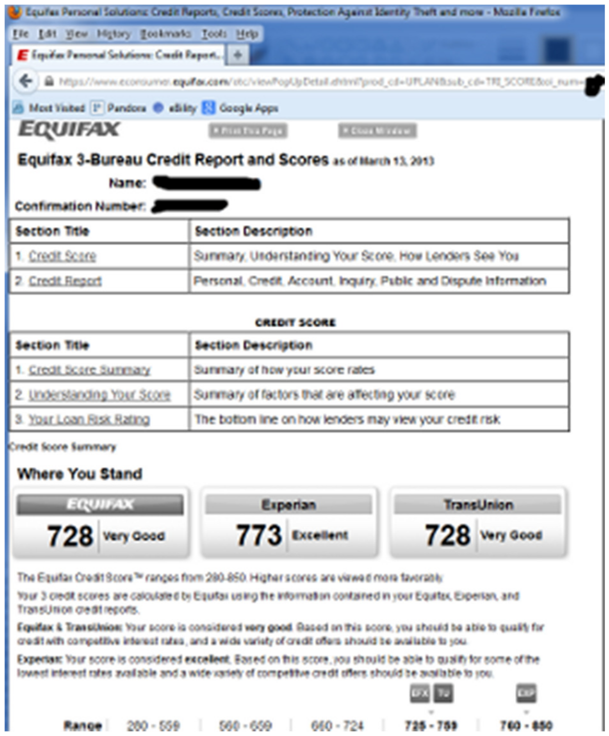
ALLSTATE	Auto insurance policy documents
E-BILLITY	Worker summary reports

ERENTERPLAN	Customer names, addresses, and telephone numbers

The following sites sent sensitive information without any cache-related HTTP headers at all:

ARGUS HEALTH	Customer names and pharmacy claims, including the names of prescription medications
BOSCOV'S CHARGE CARD	Full account statements, including the full card number
EQUIFAX	Full credit reports and credit scores
GEICO	Customer names, addresses, the customer date of birth, and the last four digits of the customer's social security number
METLIFE	Customer names, policy numbers, policy amounts, and beneficiary names
PNC BANK	Check images
T. ROWE PRICE	401(k) balances
TOYOTA FINANCIAL	Customer names, addresses, account numbers, and VINs
TRADE KING	Account numbers and balances

Below are screenshots of some of the data we recovered from the disk cache.


Equifax Personal Solutions: Credit Reports, Credit Scores, Protection Against Identity Theft and more - Mozilla Firefox
File Edit View History Bookmarks Tools Help
Equifax Personal Solutions: Credit Report...
https://www.econsumer.equifax.com/otc/viewPopUpDetail.ehtml?prod_cd=UPLAN&sub_cd=TRI_SCORE&oi_num=[redacted]
Most Visited Pandora eBility Google Apps
EQUIFAX
Print This Page
Close Window

Equifax 3-Bureau Credit Report and Scores as of March 13, 2013

Name: [redacted]

Confirmation Number: [redacted]

Section Title	**Section Description**
1. Credit Score	Summary, Understanding Your Score, How Lenders See You
2. Credit Report	Personal, Credit, Account, Inquiry, Public and Dispute Information

CREDIT SCORE

Section Title	**Section Description**
1. Credit Score Summary	Summary of how your score rates
2. Understanding Your Score	Summary of factors that are affecting your score
3. Your Loan Risk Rating	The bottom line on how lenders may view your credit risk

Credit Score Summary

Where You Stand

EQUIFAX	Experian	TransUnion
728 Very Good	773 Excellent	728 Very Good

The Equifax Credit Score™ ranges from 280-850. Higher scores are viewed more favorably.

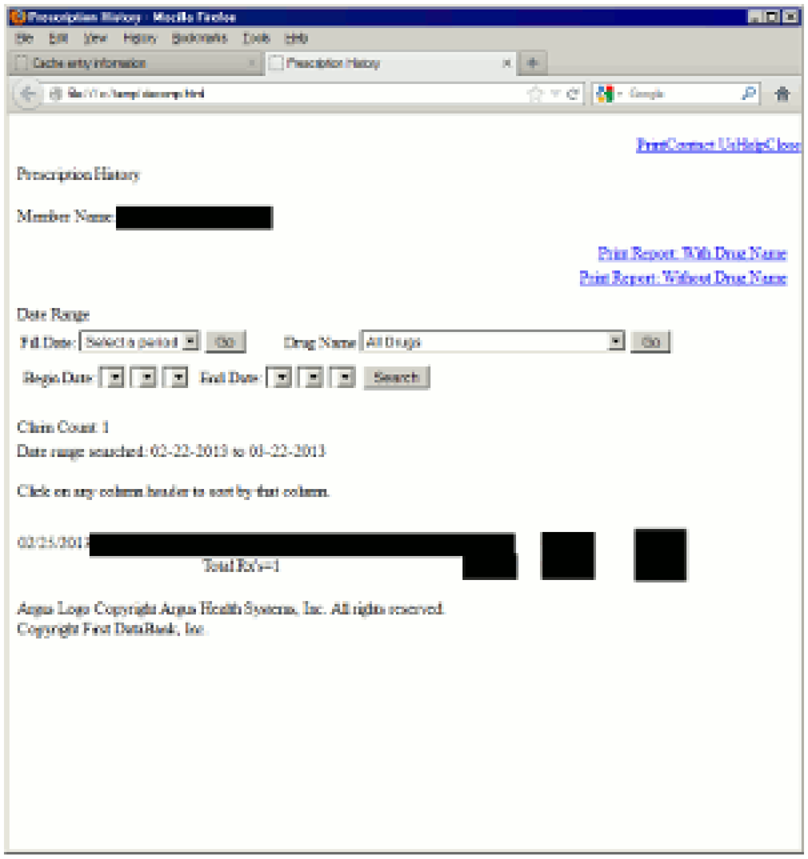
Your 3 credit scores are calculated by Equifax using the information contained in your Equifax, Experian, and TransUnion credit reports.

Equifax & TransUnion: Your score is considered **very good**. Based on this score, you should be able to qualify for credit with competitive interest rates, and a wide variety of credit offers should be available to you.

Experian: Your score is considered **excellent**. Based on this score, you should be able to qualify for some of the lowest interest rates available and a wide variety of competitive credit offers should be available to you.

Range | 280 - 559 | 560 - 659 | 660 - 724 | **725 - 759** | **760 - 850**

Figure 1. Credit report from Equifax.


Prescription History - Mozilla Firefox
File Edit View History Bookmarks Tools Help
Cache entry information
Prescription History
Google

PrintContact UsHelpClose

Prescription History

Member Name: [redacted]

Print Report: With Drug Name
Print Report: Without Drug Name

Date Range
Fill Date: Select a period Go Drug Name: All Drugs Go
Begin Date: End Date: Search

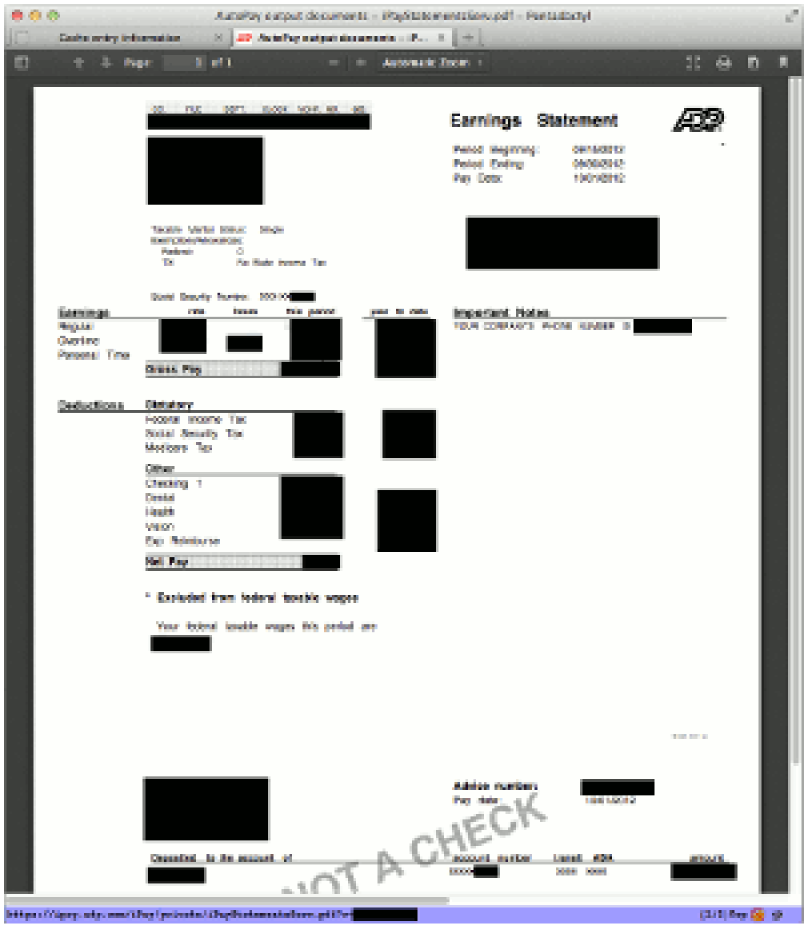
Claim Count: 1
Date range searched: 02-22-2013 to 03-22-2013

Click on any column header to sort by that column.

02/25/2013 [redacted] [redacted] [redacted]
Total Rx's=1

Argus Logo Copyright Argus Health Systems, Inc. All rights reserved.
Copyright First DataBank, Inc.

Figure 2. Prescription history from Argus.



Earnings Statement

[redacted]

[redacted]

Period Beginning: [illegible]
Period Ending: [illegible]
Pay Date: [illegible]

[redacted]

Social Security Number: XXX-XX-[redacted]

Earnings	rate	hours	this period	year to date
Regular	[redacted]	[redacted]	[redacted]	[redacted]
Overtime				
Personal Time				
Gross Pay			[redacted]	

Important Notes
YOUR COMPANY'S PHONE NUMBER IS [redacted]

Deductions	Statutory	this period	year to date
	Federal Income Tax	[redacted]	[redacted]
	Social Security Tax		
	Medicare Tax		
	Other		
	Checking 1	[redacted]	[redacted]
	Dental		
	Health		
	Vision		
	Exp Reimburse		
	Net Pay	[redacted]	

* Excluded from federal taxable wages

Your federal taxable wages this period are
[redacted]

[redacted]

Advice number: [redacted]
Pay date: [illegible]

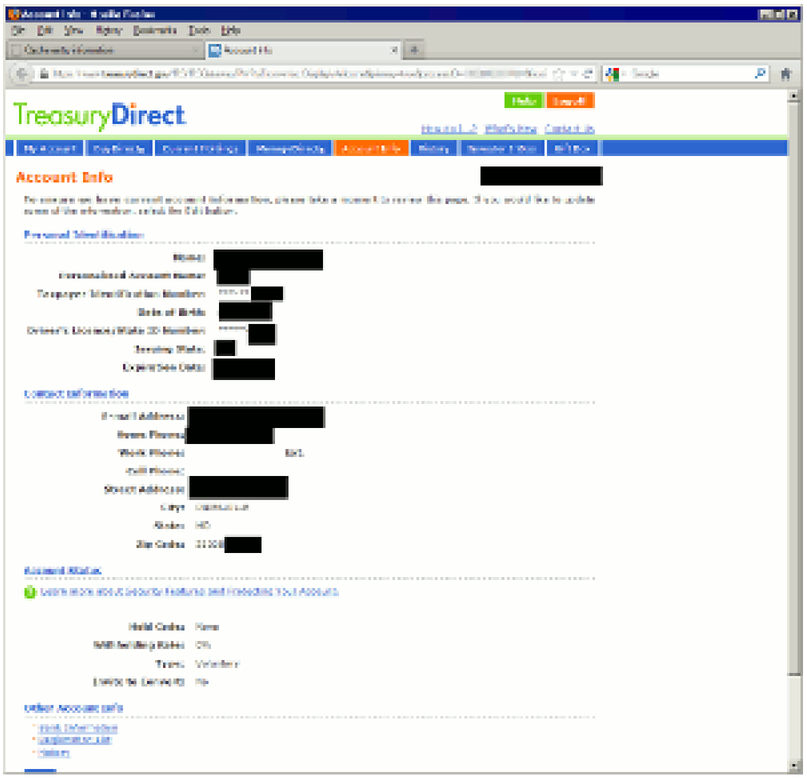
NOT A CHECK

Deposited to the account of [redacted]

account number	transit ABA	amount
XXXX[redacted]	XXXX XXXX	[redacted]

https://ipay.adp.com/iPay/private/iPayStatementsStore.pdf?r=[redacted]

Figure 3. Earnings statement from ADP.



TreasuryDirect

Account Info [redacted]

[illegible]

Personal Identification

Name:	[redacted]
Personalized Account Name:	[redacted]
Taxpayer Identification Number:	[redacted]
Date of Birth:	[redacted]
Driver's License/State ID Number:	[redacted]
Issuing State:	[redacted]
Expiration Date:	[redacted]

Contact Information

E-mail Address:	[redacted]
Home Phone:	[redacted]
Work Phone:	Ext.
Cell Phone:	
Street Address:	[redacted]
City:	[illegible]
State:	MD
Zip Code:	2120 [redacted]

Account Status

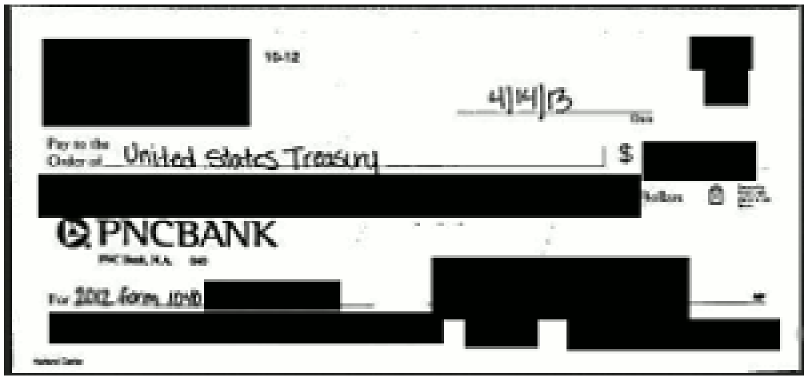
Learn more about Security Features and Protecting Your Account.

Hold Code:	None
Withholding Rate:	0%
Type:	Voluntary
[illegible]	No

Other Account Info

- Bank Information
- [illegible]
- History

Figure 4. Account information from TreasuryDirect.



[redacted] 10-12

[redacted]

4/14/13 Date

Pay to the Order of United States Treasury $ [redacted]

[redacted] Dollars

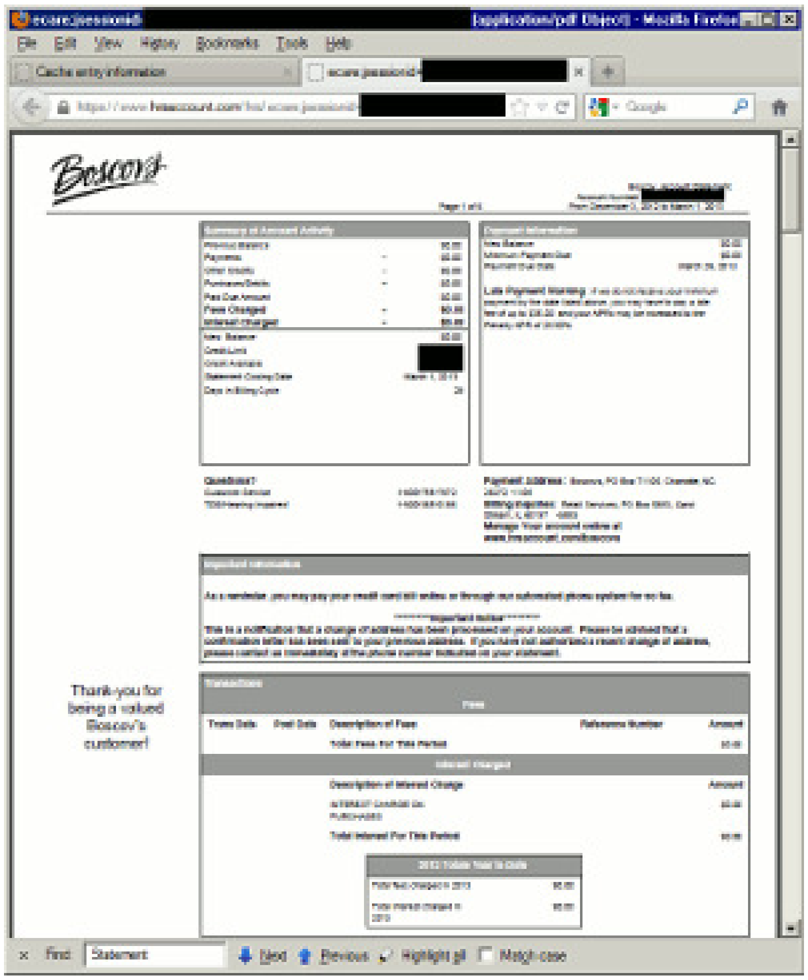
PNCBANK

PNC Bank, N.A.

For 2012 form 1040 [redacted]

[redacted]

Figure 5. Check image from PNC.


ecare;jsessionid= [redacted] [application/pdf Object] - Mozilla Firefox
File Edit View History Bookmarks Tools Help
Cache entry information
ecare;jsessionid= [redacted]
https://www.fnbaccount.com/fn/ecare;jsessionid= [redacted]
Google
Find: Statement
Next
Previous
Highlight all
Match case

Boscov's

[illegible]
Account Number: [redacted]
Page 1 of 1 [illegible]

Summary of Account Activity

Previous Balance		$0.00
Payments	-	$0.00
Other Credits	-	$0.00
Purchases/Debits	+	$0.00
Past Due Amount		$0.00
Fees Charged	+	$0.00
Interest Charged	+	$0.00
New Balance		$0.00
Credit Limit		[redacted]
Credit Available		
Statement Closing Date		March 1, 2013
Days in Billing Cycle		28

Payment Information

New Balance	$0.00
Minimum Payment Due	$0.00
Payment Due Date	March 26, 2013

Late Payment Warning: [illegible]

Questions?
Customer Service [illegible]
TDD/Hearing Impaired [illegible]

Payment Address: [illegible]
Billing Inquiries: [illegible]
Manage Your account online at
[illegible]

Important Information

As a reminder, you may pay your credit card bill online or through our automated phone system for no fee.

*******Important Notice*******
This is a notification that a change of address has been processed on your account. [illegible]

Thank-you for being a valued Boscov's customer!

Transactions

Fees

Trans Date	Post Date	Description of Fees	Reference Number	Amount
		Total Fees For This Period		$0.00

Interest Charged

Description of Interest Charge	Amount
INTEREST CHARGE ON PURCHASES	$0.00
Total Interest For This Period	$0.00

2013 Totals Year to Date

Total fees charged in 2013	$0.00
Total interest charged in 2013	$0.00

Figure 6. Boscov's Charge Card Account statement with account number.

Updates

We notified each company by email to the security– or phishing–related email address, or when email was not available, using a web-based contact form. The following companies acknowledged our advisories with a non-automated response:

- Argus Health
- M & T Bank
- PayPal

The following companies have made at least some progress in correcting the issue:

- BB&T. The account summary page is now sending Cache-Control: no-store, but check images are still sent with inadequate protections.

Observations and Concerns

We believe that the amount of personal data that is currently being written to the disk cache when visiting these sites is alarming. It is important to note, however, the distinction between a user consciously selecting a "save to disk" option, e.g., to save a bank statement, and content silently being written to the disk cache without users' knowledge. Non-technical users likely believe that if, after visiting a site and viewing personal data, they logout and close their browsers, that their data will be safe. Our findings prove this assumption incorrect in 70% of the cases tested.

Based on the quantity of sites (twelve of twenty-one) that sent at least one cache-related header, even if it was not the one mandated by the standard to prevent disk caching, we do not believe that it is intended by these industries that this content be written to the disk cache. More significantly, the maintainers of these sites may erroneously believe that they have set the required headers to prevent disk caching, based on outdated and incorrect information published on the Internet. One tutorial [11] correctly states the purpose of all of these headers, but does not put them in the proper context with regard to HTTPS, stating “SSL pages are not cached (or decrypted) by proxy caches,” which, while true for proxies, does not address the behavior of browsers. An OWASP page [12] incorrectly asserts that “If a web page is delivered over SSL, no content can be cached.” When even the security community makes outdated and incorrect assumptions about this issue, it is unrealistic that more generally-focused web developers will do better.

Web browser authors, with the most striking example being Mozilla, seem unconcerned with shifting the responsibility of discretion as to which HTTPS pages are safe to disk cache to the server. A comment on the bug report involving the change to Firefox 4's SSL caching policy by a member of Mozilla Corporation's security team stated “Among sites that don't use cache-control:no-store, the correlation between "SSL" and "sensitive" is very low” [8]. Our findings show that this assertion does not hold when real-world sites are examined, even two years after the change.

The fact that the unencrypted, disk cached data is only stored on the user's personal machine should not be discounted. The possibilities for this information to be exposed are numerous: malware infections, theft of laptops and mobile devices, theft of physical backup media or compromise of “cloud” backup services, shared machines and user accounts, and of course, shared computers in libraries, hotels, and Internet cafes. An Intel-sponsored Ponemon Institute study estimated the cost of recovering from the loss or theft of a single laptop as $49,246 [13], and a Lookout Mobile Security study estimated that lost and stolen phones cost consumers more than $30 billion in 2012 [14].

Recommendations

TO WEB DEVELOPERS AND WEB FRAMEWORK AUTHORS

Developers of web applications and web frameworks should audit all existing code to ensure that sensitive data is appropriately labeled with caching directives. Professionals in these fields must become more familiar with the fine details of the HTTP standard, and assume that browser software will always make performance vs. security trade-offs against security. Proper security assessments of sites containing sensitive information should be conducted regularly, and an examination of disk cached content across all supported browsers should be part of that assessment process.

TO THE SECURITY COMMUNITY

All existing guidance and advice in regard to the HTTPS caching issue should be revised to reflect the reality of the HTTP standard. Security professionals should be cautious in making assertions or recommendations based on working knowledge alone, and be sure to consult the relevant standards and perform testing to back up their beliefs.

TO WEB BROWSER AUTHORS

In a time where security threats and identity theft are rampant, all browsers should adopt an opt-in only policy for caching sensitive data to disk; and further, users should have an easily accessible option to refuse any or all opt-in directives. At the very least, we recommend that browsers with a very strict opt-out HTTPS disk caching policy, such as Firefox and Chrome, consider interpreting the HTTP headers and meta tag introduced by Internet Explorer, as well. Internet Explorer has been disk caching HTTPS content for far longer than either of these browsers, so many sites seem to have been developed with IE-centric security assumptions in mind.

TO END-USERS

Users should make the following configuration changes, depending on each browser:

Internet Explorer. Internet explorer already abides by most web application attempts to prevent disk caching. To further restrict what can be cached, a user can open Internet Options, choose the "Advanced" tab, and under "Security," check "Do not save encrypted pages to disk." This option may have unwanted side effects, such as interfering with file downloads from HTTPS sites [4]. Alternatively, use "InPrivate Browsing" mode.

Firefox. Install our "HTTPS Caching Controller" Firefox add-on, which adds a toolbar button allowing disk caching of SSL content to be disabled or enabled at any time. This add-on works only on the desktop version of Firefox. Manually, or on the mobile version, navigate to `about:config`, enter the preference `browser.cache.disk_cache_ssl`, and double-click to switch the value from `true` to `false`. Alternatively, use "Private Browsing" mode.

Chrome. Install our "HTTPS Caching Controller" Chrome extension, which adds a toolbar button allowing disk caching of SSL content to be disabled or enabled at any time. The extension works by injecting the `Cache-Control: no-store` header into HTTPS responses. Alternatively, use "Incognito" mode.

Our Chrome extension works only on the desktop version of Chrome, and not on the mobile Android Browser. Android users can switch to another browser, such as the mobile version of Firefox, or use "Incognito" mode.

Safari. Safari users (both desktop and mobile) need not take any action, since, as of this writing, Safari does not cache any content transferred over HTTPS.

General. In addition to taking these precautions, never log into account-related or other security-sensitive sites from a computer or other device you do not own and control.

References

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Note: this page omits the fourth, standard method to prevent disk caching (Cache-Control: no-store).

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