

Executive Summary

Project Title: Technology and Practices to Reduce Mobile Air Conditioning Refrigerant Emissions by 50 Percent at Vehicle Service and Vehicle End of Life; Associated Education and Outreach

Project Overview: Purpose and Background

According to the National Oceanic and Atmospheric Administration (NOAA), 20 percent of the HFC-134a in equipment is emitted to the atmosphere each year. According to the U.S. EPA, total mobile A/C emissions in 2004 were 24,539 metric tons (52% of total U.S. HFC-134a emissions). This increase of HFC-134a being found in the atmosphere is one reason the European Community is banning its future use in Europe, and the U.S. Environmental Protection Agency and individual states like California are focusing their attention on the issue.

Since June 2005, more than 100 industry experts have been intensely involved in research to implement “Improved Mobile Air Conditioning” (I-MAC), a cooperative research project organized under the auspices of the Society of Automotive Engineers (SAE) and supported by \$3 million in industry and government contributions. I-MAC members are pledged to increase A/C energy efficiency by at least 30% and to decrease refrigerant emissions by 50%.

Four teams were organized to address different aspects of I-MAC. One focused on the efficiency of mobile air conditioning systems. Another worked to reduce the overall system charge and leakage from hoses, seals and other sources of emission during normal operation of the system. A third team explored ways to reduce solar load and heat input into the passenger compartment. The fourth team addressed reduction of refrigerant emissions during service and repair, and at vehicle end-of-life.

This report details the work of the fourth I-MAC team (Service Team) to identify improved service tools and equipment, procedures and strategies to reduce refrigerant emissions at service and make recommendations for vehicle end-of-life refrigerant recovery.

Timing of Project

Work on this project began during the third quarter of 2004. The federally funded portion of this project began on Jan. 1, 2005 and is planned for completion by June 30, 2007.

Summary of Approaches

Six working groups comprised of 35 industry experts were established and addressed priorities which were initially identified by surveying the service industry and consulting automotive engineers and other experts on service and repair.

1. Working Group 1: Leak Detection Tools and Procedures
2. Working Group 2: Refrigerant Recovery/Charging Equipment and Procedures
3. Working Group 3: Field Coupled Hose Assemblies

4. Working Group 4: Develop HFC-134a Mass Balance for U.S. Mobile A/C Service Market
5. Working Group 5: End-of-Life (EOL) Vehicles
6. Working Group 6: Communication, Education, Outreach

Conclusions/Recommendations

Research and investigation, testing and analysis suggest that HFC-134a emissions from mobile air conditioning in the U.S. could potentially be reduced by millions of pounds annually with the introduction and implementation of tools, equipment, techniques, procedures and policies as follows:

1. More efficient refrigerant recovery and more accurate charging equipment and procedures.
2. Improved leak detection (tools and procedures).
3. Mandatory repair of A/C system leaks before system recharge.
4. Quality components; correct installation and connections.
5. Reduction of emissions from refrigerant container heels.
6. Elimination of DIY recharge of leaking systems.
7. Better compliance with recovery requirements and more efficient recovery at vehicle end of life.
8. Restricting sale of refrigerant only to certified technicians.

Team Members

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Achievements of Working Groups

1. Working Group 1: Leak Detection Tools and Procedures

This working group has tested and evaluated the current generation of leak detection tools and has identified required improvements. The group's research indicates that current technology allows detection of refrigerant leaks as small as four grams per year per joint, compared to the current standard of 14 grams per year per joint. Further, this degree of sensitivity can be achieved with the probe moving 3/8 of an inch from the leak, an increase from the current standard of 1/4 of an inch. A new standard for leak detection tools incorporating these and other improvements, including closer to "real world" testing of tools, has been published (SAE J2791). The new draft standard was presented to the Society of Automotive Engineers (SAE) Interior Climate Control Committee (ICCC) in early December 2006 for additional review and comment by members of the industry. It was approved by SAE and published in January 2007.

The group is continuing to work on new procedures for the use of leak detection tools, including detection of evaporator and compressor shaft seal leaks.

Information regarding improved tools and improved procedures for leak detection is being distributed through the automotive trade press and incorporated in training material being conveyed to the service industry.

2. Working Group 2: Refrigerant Recovery/Charging Equipment and Procedures

This working group has conducted testing using carefully recorded conditions and precise weighing and measuring equipment to determine how much refrigerant is removed from various types of air conditioning systems, with ambient temperature and the application of engine heat as variables. Results of these tests indicate that as much

as 50 percent of the refrigerant in a system may not be recovered using existing equipment and techniques, and may therefore be vented during repair or at vehicle salvage. Further studies have shown that recovery can be improved with equipment that can achieve deeper vacuum levels. A new standard for refrigerant recovery and charging equipment incorporating these and other improvements has been published (SAE J2788). The new draft standard was presented to the Society of Automotive Engineers (SAE) Interior Climate Control Committee (ICCC) in early December for additional review and comment by members of the industry. It was approved by SAE and published in December 2006.

During other industry studies it was determined that refrigerant recovery and charging equipment did not provide accurate measurement of refrigerant being transferred. Previous SAE equipment standards did not address the accurate refrigerant measurement issue. New requirements were added in SAE J2788 addressing accurate refrigerant transfer measurement. This will help reduce the amount of new refrigerant required since more accurate A/C system charging can be accomplished.

Information regarding improved tools and improved procedures for refrigerant recovery and recharge are being distributed through the automotive trade press and incorporated in training material being conveyed to the service industry.

3. Working Group 3: Field Coupled Hose Assemblies

Based on the responses to an I-MAC Service Team survey conducted in 2005, approximately 40 percent of service shops make their own coupled hose assemblies, and there is evidence that given the potential variance in parts, crimping designs and techniques, such assemblies might be prone to leaking. This working group has tested manually-coupled hose assemblies and notes that "in order to effectively reduce emissions from leaking hoses, the field coupler will have to go through a large transition in education, capabilities and mind set."

The working group has produced a draft standard for field assembled hoses and work on that standard is near completion. Information regarding how to improve field assemblies and how to field test the assemblies will be developed and distributed through the automotive trade press and incorporated in training material to be conveyed to the service industry.

4. Working Group 4: Develop HFC-134a Mass Balance for U.S. Mobile A/C Market

This group worked to identify and quantify the various emissions sources of HFC-134a related to mobile air conditioning, then prioritize target emissions and determine how best to track progress as improvements are developed and implemented. Work focused on collecting the best available information and statistics to estimate potential emission reductions.

The group developed and recommended strategies for lowering emissions from identified sources. Development of information and education for the industry has been part of this effort.

5. Working Group 5: End-of-Life (EOL) Vehicles

This group has researched and tentatively quantified potential emissions from EOL vehicles. There are indications from several studies and reports that, while refrigerant recovery from EOL vehicles is required by regulations, compliance with regulations could be improved. Research by another group within the I-MAC Service Team also suggests that recovery of refrigerant from EOL vehicles is particularly difficult, since engine heat cannot be used to enhance recovery, and recovery is likely to occur in ambient temperatures not conducive to full system recovery. The Service Team contacted management of the Automotive Recyclers Association (ARA) to open a dialogue about how refrigerant recovery at EOL can be improved, and how the team could assist. The team drafted an article about the importance of EOL refrigerant recovery which was published in 2006 in ARA's trade publication. ARA has cooperated in this effort by assisting with communications and research. Work is ongoing to achieve the goal of reduced emissions in this sector.

6. Working Group 6: Communication, Education, Outreach

MACS has worked to inform and educate the industry about the importance of refrigerant emission reductions through its technical publications and magazines, through its website, through other automotive associations, through the consumer and trade press, through a series of 60 clinics presented to industry technicians throughout the U.S. each year (2005 – 2007), through national and international automotive trainer organizations and through presentations to industry technicians in large national and international forums.

Working Group 1: Leak Detection Tools and Procedures

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Following are key elements of SAE J2791:

- The detector shall have at least three scales that can be manually selected: (1) 4 g/yr (0.15 oz/yr); (2) 7 g/yr (0.25 oz/yr); (3) 14 g/yr (0.5 oz/yr).
- The probe tip passes the specified calibrated leak at a rate of 75 mm (3 in) per second, from a distance of 9.5 mm (3/8 in).
- The probe must indicate the leak within two seconds of passing the calibrated leak standard orifice from the 9.5 mm (3/8 in) distance and clear within two seconds, at least nine of 10 times, or it fails.
- Although false triggering is allowed by this standard for many chemicals, it is not allowed for mineral engine oil or transmission oil.

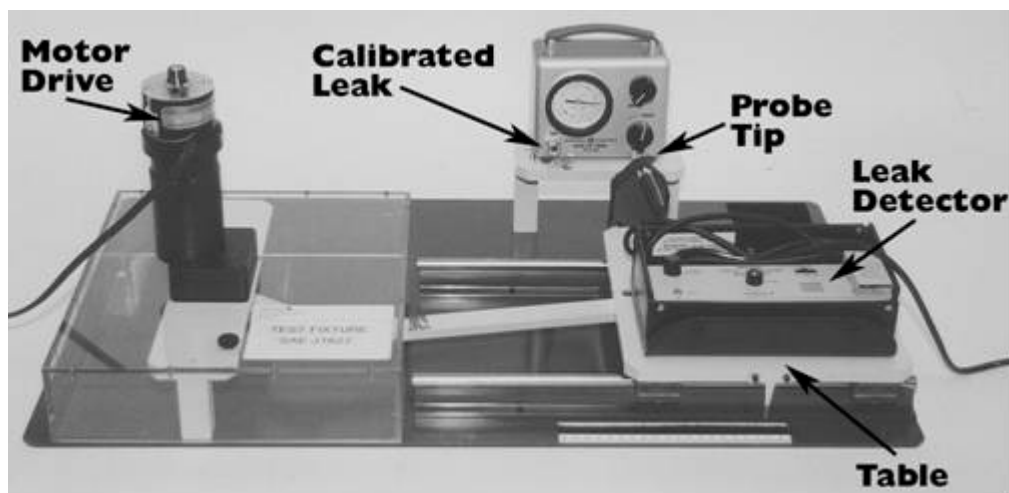
The new generation of leak detectors, designed to meet SAE J2791, are still in development, but will likely be brought to market in 2007.

There are other aspects of leak detection that are being studied, for evaporators and compressor shaft seals, but these are still in the laboratory testing phase.

Background

There are some who insist that electronic leak detectors currently in use in the field are poor. But others claim they find the leaks almost every time. The latter group believes a lot of the problem is due to use of cheap leak detectors, lack of maintenance, and poor technique.

Admittedly, a significant issue was the limitations of the previous SAE leak detector standard, SAE J1627. The manufacturer produces a tool that meets a well-defined standard. That also would be a type of device that can be produced by more than one manufacturer. SAE's Interior Climate Control Committee (ICCC) normally wouldn't approve a standard that can be met only by a manufacturer with specific, patented technology, unless perhaps the technology was widely licensed.



A test table with a swing-arm was used for the SAE J1627 tests. Times are specified for the detector to inhale the leak sample, analyze it, sound the alarm and then shut off. The detectors that passed this HFC-134a test were a major upgrade from what had been available for CFC-12.

During the development of the previous standard, SAE J1627, there were objections from manufacturers of corona discharge leak detectors, who said it was so restrictive as originally proposed that they couldn't meet it with the best adaptations of corona discharge technology. They said that unless the ICCO modified the proposed standard, the only detectors that would meet it were many times the price of their equipment, those with "heated diode" technology.

They probably were quite right, so the standard was not as restrictive as it could have been. "Functional" room was left for the makers of corona discharge detectors. Remember, HFC-134a is many times more difficult to detect than CFC-12 and the job was not going to be easy. Really small leaks were not a major concern at the time of the refrigerant changeover, because it was thought that HFC-134a was an environmentally friendly refrigerant.

In fact, an early concern was that larger leaks would be the real problem because of the higher pressures and smaller molecules of the HFC-134a system. It turned out in most cases that HFC-134a systems have been reasonably tight. And when SAE J1627 was developed, the systems had a fair amount of reserve refrigerant, often a half-pound or more. The 1995 General Motors 'N' cars (Pontiac Grand Am, Olds Achieva and Buick Skylark) had a total refrigerant charge of 36 ounces. Similar 2005 models (Chevrolet Malibu and Pontiac G6) have a refrigerant charge of less than 18 ounces, a reduction of 50 percent. As the vehicle manufacturers reduced the system refrigerant charge, reserve refrigerant amounts were also reduced. In the mid-1990's there were concerns about the detectors "false triggering," and that's a problem that is unlikely to be solved completely. The detector sensors that sniff HFC-134a also respond to alcohols and a lot of other chemicals that may collect in underhood and powertrain crevices, including

lubricants. The sensors also may be triggered by adhesives and foam seals used in HVAC cases.

It's likely that some detectors' sensing technologies can be engineered to resist false-triggering from lubricants. However, some amount of cleanup along the refrigerant circuit may have to be a preparatory step to checking with an electronic leak detector, and even if it can't be done everywhere, it's important to clean and then recheck the area where a leak appears to be present.

Compressor Shaft Seal Leaks

A compressor shaft seal leak is one of the most difficult challenges. There are only a few ways to find a shaft seal leak, and all but one (a laboratory test) will not indicate the size of the leak. In the new era of refrigerant conservation, one is likely to be looking for relatively small shaft seal leaks, perhaps no more than one third-ounce or about 10 grams per year.

The A/C operates about four percent of the vehicle lifetime. So system-running leakage could be as much as 20 times the system-off (static) leakage rate and still not be a service issue, assuming that total leakage rate was small enough over the life of the compressor. Example: a compressor has a static leak rate of 5 g/yr or about 1/6th ounce. If the leak rate with the compressor operating were 20 times that (100 g/yr), the overall effect would be about the same because the compressor operates only 1/20th as long as it's off. However, there's another issue. The leakage rate also increases with ambient temperature, so there are two situations where leakage could be very high: leakage in system operation and leakage in hot soak. Even with the system off, ambient temperature must be factored into the annual leakage rate.

Compressor leakage can't be checked while it's running. But with today's small-charge systems, seemingly-low leakage rates soon could lead to a performance issue. Right now, the usual shop test procedure is one of the following:

- Wait for trace dye to seep out of the shaft seal area and drip to the bottom of the compressor. Trace dye must circulate in the system so it may take a period of time. This works, unless there's a hub well in which the oil collects or a wick by which the oil is absorbed. It's often necessary to remove the clutch to see if there's trace dye showing up at the shaft seal.
- Check for a leak with an electronic detector as soon as the system is shut off. Leakage can't safely be checked with the compressor running, and even if that were possible, it's likely the spinning clutch would cause refrigerant dispersion and make detection practically impossible.

Shops that claim they get the best results are perhaps just finding the very large leaks. Or, perhaps after disconnecting the electric cooling fan or blocking the condenser to build up system pressures, they work quickly during the brief after-shutdown period when pressures are equalizing and low-side pressures may reach 150 p.s.i.

If a shop is in a really hot area, a technician may be able to check for leakage under

hot-soak conditions when low-side pressures can exceed 250 p.s.i. These procedures raise questions. Are the technicians really detecting an operating leak, or one that just shows up during pressure equalization, or both? Where do they check? Some check the compressor nose, while others run the detector over the bottom of the clutch gap. Both areas should be checked. Neither procedure tells how large is the leak, or under what conditions (static, dynamic, different temperatures) the leak is significant.

The Leak Detection Problem Will Get Worse

Today's smaller charge systems are much tighter – they have to be because they may have a charge tolerance of under an ounce. Older A/C systems had 6-8 ounces or more of extra refrigerant in the receiver-dryer or accumulator to compensate for leakage, but the newer systems have only perhaps 1.5 to 3 ounces (42-85 grams) of extra refrigerant. If a system is seeping refrigerant at a rate of 3-5 grams/yr from each of ten fittings, plus a normal 5-7 g/yr from each service valve, plus 15 g/yr (0.5 oz) from the compressor shaft seal, that's a total loss of around 70 g/yr (approx .25 oz) or more. That would mean a modern small-charge system could lose enough refrigerant in a year to create a loss of cooling performance in high-load conditions.

That's not acceptable, and the apparent fact is that most new systems will go perhaps five to seven years without adding refrigerant. That indicates new compressors and joints perform better than these numbers. However, there hasn't been a lot of long-term experience with these small-charge systems. They might get even smaller and obviously will also have to get a lot tighter. The systems have to be "long-term tight," to compensate for the smaller charges.

The industry wants to insure its total system leak is less than 20 grams per year over their lifetime or at least 10 years.

Detecting "Active" Leaks

There is a concern about an ultra-sensitive detector indicating leaks so small they can't be repaired. As the probe is moved, it continuously draws in refrigerant samples for analysis by the detector. It is possible the probe would pick up a concentrated sample at the richest detection point of a leak, and sound the alarm for a leak smaller than 4 g/yr, if the probe were stopped or paused at a rich point. That's why continuous movement is needed. The detector maker develops his sample analysis based on the test defined in the SAE standard, and that test includes the probe moving past a calibrated leak device, not stopping on the richest detection point of the leak.

Greater detector sensitivity might enable detection of what is an active leak, one that apparently occurs only when the system is operating. It may well be that an active leak is also a much smaller static leak. There has been no test evidence on this, but it stands to reason that a leak is a leak all the time, just at different rates. It would be beneficial if the next generation of detectors picked up some of those tough leaks.

In The Meantime

Just because SAE J2791 detectors aren't available right now doesn't mean that service shops can't use the currently available ones, or ignore detector maintenance. Even the best detector won't do much if it hasn't been maintained, or if used only for quick point-and-shoot at the few fittings easily reached. Some technicians turn on a detector, crank up the sensitivity and give up when the detector starts false-triggering into a continuous buzz. One service specialist notes, "A technician just has to accept removing some of the vehicles plastic panels to reach all the refrigerant lines and fittings."

Another fact is that a \$49.99 detector or even a \$99.99 detector is likely to be a lot less discriminating than a \$400 heated-solid-state or infrared detector. Cheap detectors may pass an SAE J1627 test and even detect many leaks in the hands of a very patient technician working in a clean, dry, oil-free engine compartment. That's about all. Even with a premium detector, SAE J1628, which is the "How to Use" document that was written to accompany J1627, should be used.

Working Group 2: Refrigerant Recovery/Charging Equipment and Procedures

This working group has conducted testing using carefully recorded conditions and precise weighing and measuring equipment to determine how much refrigerant is removed from various types of air conditioning systems, with ambient temperature and the application of engine heat as variables. Results of these tests indicate that as much as 50 percent of the refrigerant in a system may not be recovered using existing equipment and techniques, and may therefore be vented during repair or at vehicle end-of-life. Further studies have shown that recovery can be improved with equipment that can achieve deeper vacuum levels. A new standard for refrigerant recovery and charging equipment incorporating these and other improvements has been published (SAE J2788). The new draft standard was presented to the Society of Automotive Engineers (SAE) Interior Climate Control Committee (ICCC) in early December 2006 for additional review and comment by members of the industry. It was approved by SAE and published in December 2006.

Factors in Refrigerant Recovery

The amount of refrigerant you can recover from a system depends on how much is in the system, of course, but also ambient temperature, the technique you use, and the performance of the recovery machine itself. When you try to draw out the refrigerant, the vacuum lowers the temperatures in the system; the oil chills and forms a virtually impenetrable blanket over some of the refrigerant. Further, as the refrigerant is removed, other system components also cool resulting in lower refrigerant pressure.

Obviously it helps if you warm up the system with engine operation, heat up the evaporator by putting the system in maximum reheat, controls on recirc, doors and windows closed, and apply heat to the accumulator. Tests performed for the SAE I-MAC research program indicate that you can remove a higher percentage of the refrigerant by applying heat and performing recovery after the early morning ambient chill has gone.

It's also apparent that there are big differences in the percentage of refrigerant that's recovered using best techniques versus flat-rate-oriented shortcuts.

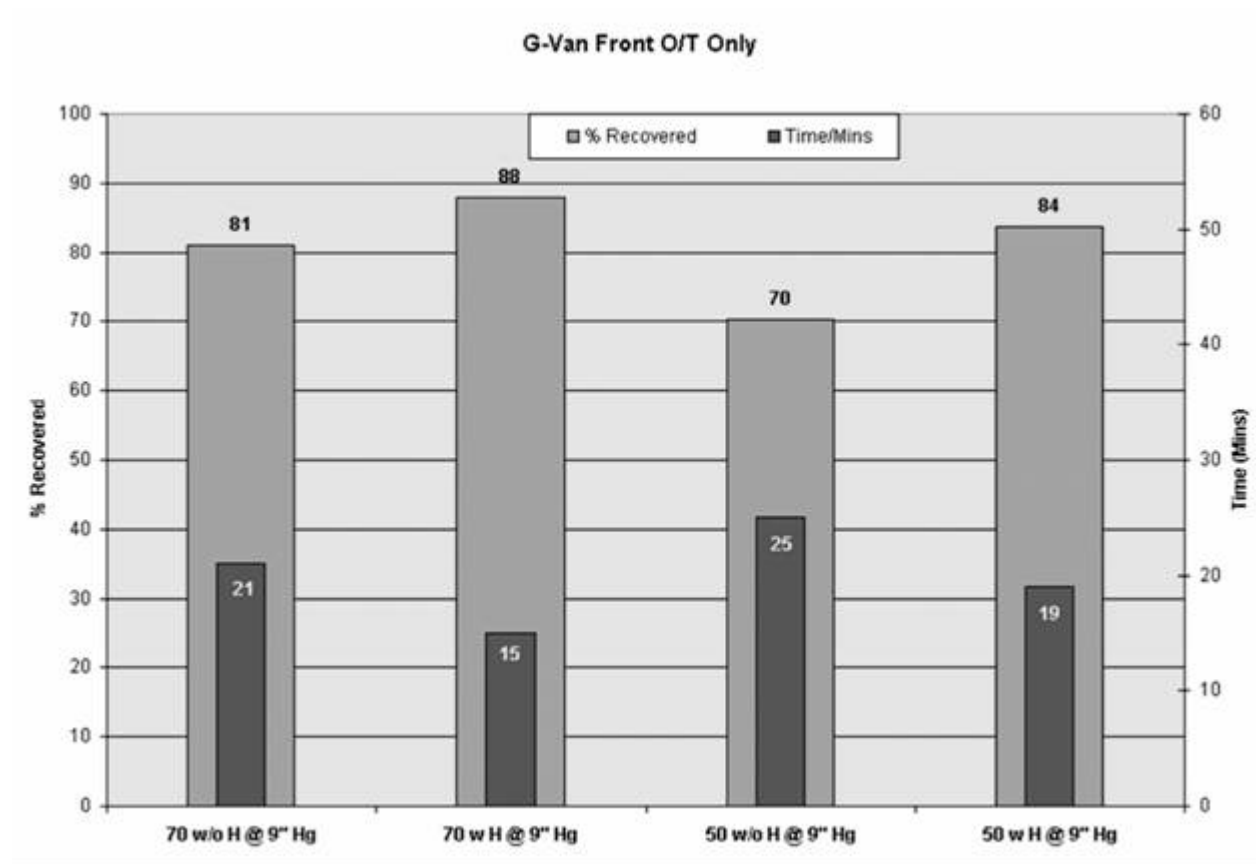
A "single pull" on a cool morning might remove 60 percent of the charge, whereas a careful procedure, using heat to promote refrigerant outgassing, might remove the more than 90 percent that is necessary for accurate service.

Recovery Tests

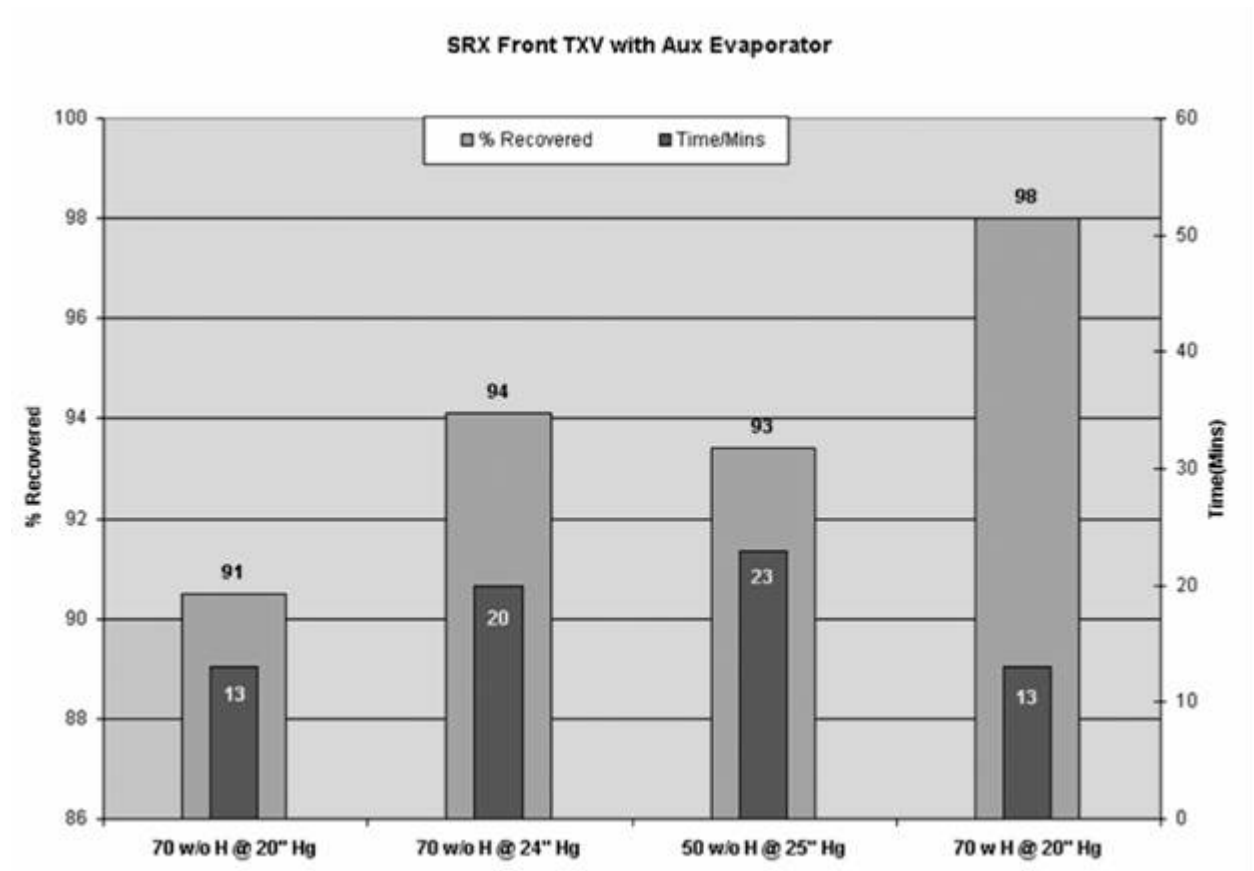
Perhaps nothing can demonstrate the facts brought out in the previous four paragraphs better than the bar charts shown on the following pages. They clearly illustrate the vast difference in the amount of refrigerant that can be recovered from a system at different vacuum levels, at different ambient temperatures, and whether or not the system was exposed to an external heat source during the recovery process. The charts contain the actual results of the SAE I-MAC research mentioned above. For extremely accurate measurement, the entire recovery/recycling machine used during the tests was placed on a scale that read/indicated the weight out to three decimal places.



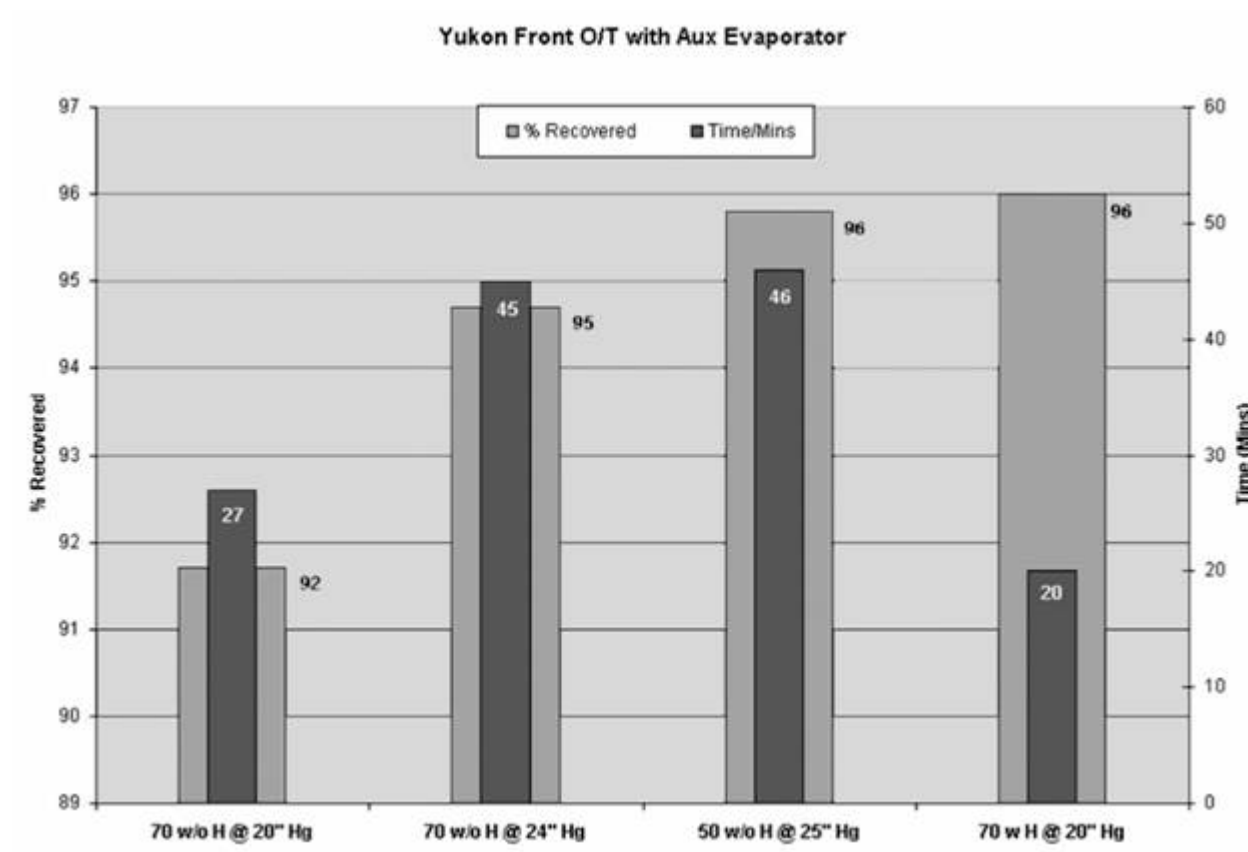
When the SAE I-MAC tests were conducted to measure how much refrigerant gets removed from a system during a "normal" recovery, for purposes of extreme accuracy, the entire recovery/recycling machine was placed on a scale that read/indicated the weight out to three decimal places.



The chart above shows the results of a careful recovery performed on a late-model GM “G” van (Chevy Express/GMC Savana). This vehicle was equipped with a single-evaporator orifice tube/accumulator system. Notice that across the chart, the maximum vacuum used was nine inches (representative of what many of today’s recovery machines produce). At 70° F, after a 21-minute “pull,” only 81% of the refrigerant was recovered. When external heat was applied to the system, even in a shorter time frame (15 minutes), 88% of the refrigerant was recovered. However, take a look at what happened when the same operations were conducted at an ambient temperature of 50° F. With no heat applied, the recovery machine left 30% of the refrigerant in the system, even with a 10-minute longer pull. The recovery rate improved when heat was applied, but after a 19 minute pull, the machine still only removed 84% of the refrigerant.



This chart shows the results when the same type of test was performed on a Cadillac SRX, and there are three main differences this time. First, the SRX has two evaporators, and it is an expansion valve/receiver/drier system. The third difference is the amount of vacuum used. Notice that a 13-minute pull at 70° F, using 20 inches of vacuum (more than what many current-design recovery machines produce) removed 91% of the refrigerant with no external heat applied. The same operation performed for 20 minutes, but at 24 inches of vacuum, withdrew 94% of the refrigerant. But even at a reduced ambient temperature of 50° F, a slightly higher 25 inches of vacuum pulled out 93% of the refrigerant in 23 minutes. And once again, as evidenced by the last bar on the chart, increased ambient temperature coupled with external heat makes a major difference. At 70° F, a lower 20 inches of vacuum pulled out 98% of the refrigerant after again being applied for 13 minutes.



This chart shows what happened when the test was run on a GMC Yukon equipped with an accumulator and two evaporators. The first and last pulls were performed at an ambient temperature of 70° F with a vacuum level of 20 inches, and both were under 30 minutes. Notice that the last pull, with additional heat, but seven minutes shorter than the first, removed 96% of the refrigerant as opposed to 92% for the first pull. The second pull, once again at 70° F with no external heat, but this time for 45 minutes at 24 inches of vacuum, removed 95% of the refrigerant. The third pull, for only one more minute than the second, but at 25 inches of vacuum, removed 96% of the refrigerant. This is particularly noteworthy, taking into consideration that it was performed at an ambient temperature of only 50° F, with no additional heat applied. The difference one inch of vacuum makes, even at a 20° F lower ambient temperature, is apparent. Also clear is the impact the amount of recovery time can have on more complete refrigerant removal.

Results of Incomplete Recovery

So what is the outcome of these tests telling us? An obvious consideration is that any refrigerant not removed from a system during recovery is refrigerant that remains in it. The results also illustrate that even if you don't physically apply heat to the system components (especially accumulators) before you start a recovery process, you should first run the engine up to operating temperature, so at least some heat will transfer to

the A/C components. But beyond those two issues, these charts, and the overall results of the tests, raise two major questions.

The first one is what happens to the refrigerant left in the system after recovery? The answer to that question is going to serve as a preamble to the second question and its answer.

What happens to that refrigerant, if the system refrigerant connections are left open for a period of time, is that it (or much of it) gets vented to the atmosphere when the pre-recharge evacuation is performed. Not only is that bad for the environment, it is also discarding perfectly good, reusable refrigerant. At the price of refrigerant today, this makes absolutely no sense.

Now, for question two: What if the vacuum pump isn't performing quite up to snuff; not performing a good deep vacuum, or, if in the interest of saving time, or for some other reason, the technician shortcuts performing a deep vacuum?

In both of these circumstances, refrigerant remains in the system, and as the charts show, depending on the type of system, ambient conditions, the recovery machine and how it's used, it could be a substantial amount. If the system is then recharged to "spec," it will be overcharged. This costs money, because more refrigerant is used than necessary, and the more jobs done this way, the more money wasted. However, and possibly even worse, overcharging a system during service can set the stage for future operational problems.

If the technician just does a typical recovery with an old machine and then goes to recharge, an overcharge is likely. Example: 16-oz. capacity, 12 ounces remaining in the system, and the technician recovers half. That leaves six ounces, so if the technician "luckily" gets close on recharge, putting in 15 oz., the system will have 21 oz. and be overcharged by a staggering 38%.

If the technician is doing a repair on another (non-A/C) system and has to recover a full charge of refrigerant to move A/C components for access to other parts, the numbers would be worse: 16 oz. charge, eight ounces remaining and 16 oz. added, resulting in a 50% overcharge.

Remember, in current reduced charge systems just two ounces error on that system can result in performance problems, and if it's undercharge, also affect compressor lubrication.

Naturally, there are differences in recovery depending on the system. An orifice tube/accumulator system is more difficult, because during recovery the accumulator becomes very cold, reducing refrigerant pressure and the oil it contains will tend to trap refrigerant, reducing the recovery percentage. A dual system (with a rear evaporator) also adds difficulty, whether it's orifice tube or expansion valve.

Guidelines for Improved Recovery

The following guidelines will help improve recovery percentages:

- As already noted, don't pull refrigerant from a system with ambient temperatures below 70° F. This is particularly important if the system is full. Instead, wait until the shop work area air temperature warms up and also run the engine at fast idle for at least 15 minutes to warm things up. Also, set the dashboard temperature control to hot, blower on high, put the system in recirc and close all doors and windows. That will help provide warm air to the refrigerant in the evaporator.
- After allowing time for the system to outgas following the first recovery, run the machine for a second recovery.
- On orifice tube systems, heat the accumulator using a hair dryer or heat gun. If you don't, the accumulator will become very cold as the recovery compressor pulls into a vacuum, trapping refrigerant under a layer of cold oil.

The New R/R/R Machines

Standard J2788 has been published by the Society of Automotive Engineers, and it officially went into effect December 2006. Among many other things, this means that after the end of 2007, manufacturers may not certify machines that qualify only under the old standard (J2210), as it has been superseded by J2788. However, shops may continue to use their existing (J2210) equipment as long as they wish unless regulatory requirements change.

The new generation of recovery/recycle/recharge machines is ready, not an engineering proposal on the horizon but actually available in the marketplace. They'll carry a small but important label, "Certified by (name of laboratory) to Meet SAE J2788, Replacing J2210." The I-MAC Service Team worked two years to develop the J2788 standard.

Until J2788 went into effect, the applicable SAE standard was J2210, which covered only refrigerant recovery and recycling equipment. J2210 was written at a time when HFC-134a was considered a virtually benign substance and the primary goal was to ensure that what was recovered was properly recycled – a vehicle system performance issue. The J2210 standard (including 1998 revision) simply required the equipment to pull down to four inches of mercury vacuum during the recovery process. It did not actually require recovery of any specific percentage of refrigerant in any specific amount of time.

Further, the air that was in the refrigerant could be manually or automatically purged, and if manually, all the machine manufacturer had to do was provide a pressure gauge and instructions to determine if there was air in the system and how to purge.

J2788 is a sea change. It covers three types of equipment (1) designed to recover and recycle refrigerant; (2) charge refrigerant, and (3) recover, recycle and recharge refrigerant – the most likely choice. In all cases, the standard requires that the equipment accurately measure the amount of refrigerant recovered from or charged into the mobile A/C system. Because all three devices are certified under the same standard

at this time, the buyer must understand that the certification coverage obviously is limited to the functions a machine is designed to perform.

The recovery is a straightforward performance requirement – 95%. There is no minimum vacuum to which the recovery compressor must pull. However, testing indicates that the next-generation machines are likely to meet the standard with more powerful compressors that draw down to far deeper vacuums than the four inches of J2210, or even more than double the nine inches of the ACR2000 used by GM dealers. A machine also might use some form of assist system to speed recovery. It doesn't matter. The bottom line is the 95% recovery performance.

Because the old standard did not cover charging, it would be possible to “mix and match,” i.e. use a J2788 recovery/recycle machine with a charging station that meets no standard. Inasmuch as accurate charging is so important, that would be an unwise choice. Further, a recovery/recycle/recharge machine will be the most logical purchase for a shop.

A machine that does recovery only (perhaps for wrecking yards) may be certified under a separate SAE J2810 standard, which has been completed and is expected to be published in July, 2007.

All machines that do recycling must purify the refrigerant to applicable SAE standards, the same as before. However, the recovery – and now the recharge function – are exacting processes in J2788.

The equipment has to pass a series of tests, including recovery of the refrigerant, recycling it and (if so designed) recharging the system. The test is performed on a 2005 – 07 Chevrolet Suburban with rear A/C and a 3.0-lb. refrigerant charge (or a full-size lab mockup of the exact system, powered by an electric motor).

The Suburban's is not the biggest system and other systems may have configurations that are more restrictive. But with an orifice tube/accumulator front system, the Suburban presents a challenge for the test objective of 95% recovery in no more than 30 minutes, accurate to within plus/minus 30 grams – one ounce.

Accumulators chill during recovery and may trap considerable refrigerant with older technology machines, unless heat is applied and time is allowed for outgassing – J2788 does not allow the laboratory to heat components during recovery. The technician is sure to find that the new machines also recover refrigerant and draw a vacuum much faster on expansion valve systems with refrigerant charges of under 1 to 1-1/2 lbs., as found in most newer cars.

If designed to charge, the machine must recharge the same system (3.0 lbs.) to within plus/minus 15 grams. The recovery accuracy has a larger tolerance (30 grams) because some refrigerant is likely to be trapped in the filter.

To tweak recovery and recharge accuracy, the service hoses must have shutoff valves at the coupling ends (where they connect to the vehicle system). So if the machine recovers the refrigerant in the hoses, it can recover it all, for maximum accuracy. J2210 allowed them to be 12 inches from the ends.

Although manual air purge was allowed in J2210, automatic air purge is required in J2788. Further, the machine must have an electronic strategy that allows time for air to separate from the refrigerant, so that air purge vents a minimum amount of refrigerant.

The machine must separate out and measure refrigerant oil that is recovered, accurate to within plus/minus 20 grams (0.7 ounces).

The machines must have these important “maintenance features”:

- A repeated warning leading to an electronic lockout when a filter reaches the end of its service life.
- A way for the shop to check the accuracy of the scale (or other measuring system if used).
- Any needed charge accuracy checking device must be included with the machine. For a scale check, manufacturers are likely to include a calibration weight.

The machine must demonstrate basic ability to work accurately in a shop environment by being rolled 20 feet across a floor and then proceed to be tested – no scale calibration allowed after the machine has been moved.

The most widely cited number for the new machines will likely be 95% recovery of refrigerant (although that’s a minimum) and equipment manufacturers may be able to offer (and advertise) better results.

That number wasn’t pulled out of the air. With a 10% charge tolerance, 95% recovery was the minimum necessary to ensure that if an accurate recharge was performed, the system would not be over or undercharged. That percentage also means that a minimum amount of time (just to get out air) could be spent on post-recovery evacuation (with a vacuum pump or the recovery compressor itself). The 95% is based on a full-charge test. If the system contains a partial charge, the recovery percentage may actually be much higher.

Certainly, the No. 1 improvement is the percentage of refrigerant recovered, No. 2 is speed, No. 3 is accuracy and No. 4 is a way to check the most critical part – whatever measures the amount of refrigerant removed from and charged into a system – almost surely a scale. And because automatic air purge is required, shops no longer face the real-world fact that they rarely if ever did it...which of course, often resulted in just-serviced systems that performed poorly because they contained air.

The test that accompanies the J2788 standard could only pit the machine against a single vehicle, the 2005-07 Chevrolet Suburban with rear air. If a late-model machine

goes through its cycle on a medium-size car with a one-pound system in under 15 minutes, recovery with the new machines will be markedly faster. If the technician is working on some older vehicles with large refrigerant charges, the technician will appreciate the powerful new recovery compressors and how fast they work. And if the technician chooses to apply some warmth to an accumulator (with a heat gun, for example), that will be a plus. But the J2788 test doesn't require it – or even allow it. In fact, only a brief period of engine and system operation is allowed for the test, to simulate a vehicle left outside and driven into a service bay and allowed to fast idle. So the J2788 equipment will not only reflect real world, but also allow the technician to recover a lot more refrigerant.

When recharging, the technician will have the confidence that the system isn't under or overcharged. As a result, and combined with its speed, the technician will be able to use the new machine as a diagnostic tool. Here's what we mean:

Is the system pressure questionable? Those manifold gauges aren't exactly precision instruments, and pressures are of no value in assessing refrigerant charge level. So if the problem is marginal or poor cooling, the speed of recovery, recycle and recharge will enable the technician to eliminate under or overcharge as an issue in a lot less time than going through some other diagnostics.

3. Working Group 3: Field Coupled Hose Assemblies

Based on the responses to an I-MAC Service Team survey conducted in 2005, approximately 40 percent of service shops make their own coupled hose assemblies, and there is evidence that given the potential variance in parts, crimping designs and techniques, such assemblies might be prone to leaking. This working group has tested manually-coupled hose assemblies and notes that "in order to effectively reduce emissions from leaking hoses, the field coupler will have to go through a large transition in education, capabilities and mind set."

The following study by a leading manufacturer indicates that field assembly of A/C refrigerant hoses is often done in ways that do not produce the kind of well sealed crimps that even approach, much less match original equipment. Yet, there are field-assembly systems out there that properly used, may meet SAE standards for factory assembled hoses.

The working group has produced a draft standard for field assembled hoses and work on that standard is near completion.

Project Purpose

Determine if field coupled aftermarket replacement flexible hose assemblies used in HFC-134a automotive refrigerant systems can meet the latest automotive industry standard leak rate requirements. Identify current field techniques and processes to determine if assemblies being placed in service are properly constructed. Establish a procedure whereby in-field hose coupling can be properly leak tested and certified.

Project Scope

To evaluate the current available designs, components and processes for field replacement fitting termination on HFC-134a flexible hose assemblies to determine if component leakage rate is compliant with current industry standards. Identify and recommend configurations which meet the proper testing criteria. Create a certification protocol that is recognized and monitored by the industry which is suitable to field operations.

Objectives

- Define the multiple categories of design and manufacturing configurations for components. Determine compliance through testing.
- Establish the latest SAE-J series testing procedures which defines the leakage rate for this class of components.
- Implement field survey in order to initiate a data base from field related issues whereby establishing a representative base line.
- Analyze data and determine design configurations which meet the leakage rate criteria and show to be the more reliable field applications.
- Create a joint collaborative agreement with local shops to assist in data collection, testing and providing samples.

- Establish procedures which provide strict controls on how field coupled replacement hose coupling will be maintained.
- Design and configure a field testing procedure which is conducive to any type of shop environment.

Data Collection Procedure

Sample Preparation:

- 1) Two discharge hoses (# 8); 18"~24" long; terminated with std. male o-ring pilot fittings; crimped collars (type of hose and fitting optional – prefer different fitting manufacturer on either end).
- 2) Two suction hoses (# 10); 18"~24" long; terminated with std. male o-ring pilot fittings; crimped collars (type of hose and fitting optional – prefer different fitting manufacturer on either end).
- 3) 12" long piece of each hose size and manufacturer used.
- 4) One piece sample of each fitting used by size and manufacturer.
- 5) One piece sample of each ferrule used by size and manufacturer.
- 6) Make sure all individual samples are properly identified/ tagged (sample provider and date).

Instructions to Sample Supplier:

- 1) Prepare each sample according to the sample preparation instructions.
- 2) Style of fitting, style of hose and material manufacturer is optional to sample supplier.
- 3) Be sure to provide (1) individual sample of each of the materials used.
- 4) Record the appropriate information into the provided spreadsheet under the heading "sample general information."
- 5) Ship all samples and information to:

Note: All photos in this section are provided courtesy of ATCO Products.



Correct 6 jaw method



Incorrect 6 jaw method (crimped, rotated, re-crimped)



Tube and hoses blade finger style; crimp not overlapping



Incorrect tube and hose combination causing tube to seriously deform



Old style 3 barb fitting



Low profile fish tail barb (inner sleeve reinforced)



Deep 4-groove rolled



Necking down of crimp area due to incorrect crimp and incorrect fitting/hose selection

Data Analysis Summary

- Large variation in crimping dimensions.
- Several different crimping styles and techniques.

- Using of “old style” fittings which are no longer recommended for use in HFC-134a applications.
- Wrong combination of parts – hose and fitting sizing.
- Two types of leak failures (1) Hose split due to incorrect sizing (2) Leaking through weep holes in outer layer of hose.
- Incorrect crimping method – double crimping.
- Possible use of old or salvaged components (fittings, hoses, etc).
- Both short and long term effects of incorrect hose coupling.

Conclusions

- Extreme inconsistency in all aspects of sizing and materials selection of field coupling hose assemblies.
- Potential failure issues being created during the utilization of reworking assemblies along with the use of salvaged materials.
- Wide variation in crimping styles, techniques and dimensional integrity.
- Both short and long term defect potentials by not complying with SAE J2064 certification process.
- Limited field expertise in the area of hose coupling. “Crimp it until it doesn’t leak” thinking.
- In order to effectively reduce the amount emissions from leaking hoses, the field coupler will have to go through a large transition in education, capabilities and mind set.

Recommendations: Shops to be Able to Comply with SAE J2064

- Must use factory certified assemblies.
- Become a certified field hose coupler using proper approved equipment (central locations or independents).
- Industry standardization of components and proper training on component matching.
- Shop testing standards which are audited by the industry.

SAE J2064

SAE J2064 is an engineering standard for joint integrity of hose couplings. The Society of Automotive Engineers standards have a major effect on how the technician performs A/C service. For example, all manufacturers’ retrofit procedures from CFC-12 to HFC-134a were based on SAE J1661. Electronic leak detectors meet SAE J1627, and the list goes on. Further, SAE standards are commonly referred to in state and federal regulations, and J2064 could be used by California and other states that are trying to reduce the greenhouse gas emissions related to global warming.

Standard J2064 is important because it covers the HFC-134a refrigerant hoses the technician replaces, and it’s been revised. The reason for the revision is refrigerant conservation, and it is an issue service technicians are obligated to work with. With smaller refrigerant charges, all the seals, joints and fittings have to be designed to leak far less.

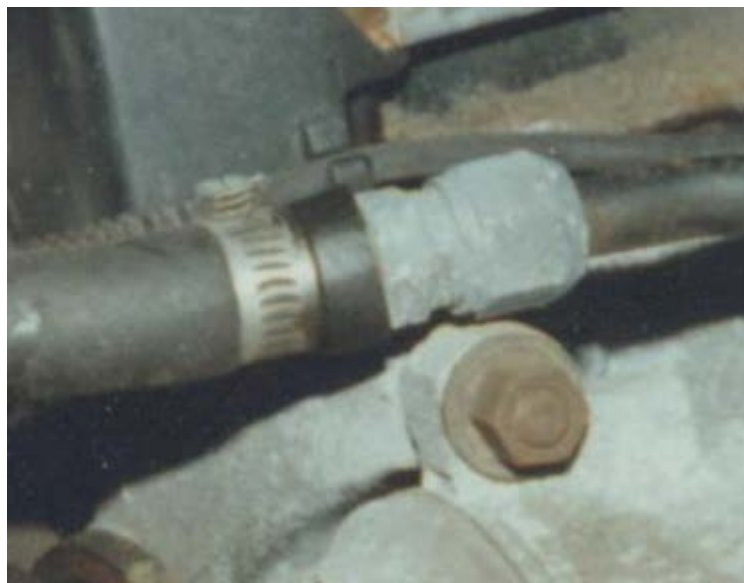
When CFC-12 systems had capacities of four pounds or more, leakage of a pound in a year was considered tolerable. What was once “normal seepage,” isn’t normal anymore, and motorists now object to both the need for frequent service and the environmental risks.

In the early-to-mid 1990s, leakage of as much as eight ounces in a year was not surprising, but not anymore. Late-model systems typically have total capacities of one to two pounds and just a few ounces lost is enough to affect performance. The industry has adjusted to that, and now the systems are getting much tighter, maybe at a faster pace than expected.

With the revised J2064 standard, hoses that are not tight enough soon could make the entire system non-compliant in the European Community, and if proposed legislation passes judicial muster, in California and other states as well.

The revised J2064 now requires that each and every coupled hose assembly meet the standard for joint integrity. Some factory assembly lines are using helium mass spectrometry for leak detection to check every hose labeled for J2064 and intended for Original Equipment use. That’s laboratory-grade equipment compared to the far-less-demanding leak test done with soap bubbles.

Surveys show that half of A/C refrigerant hose leaks are repaired in shops, instead of installing a new OEM replacement hose. And because a fifth of those shops make up hose assemblies for other shops, they have a multiplier effect.



Barb fittings with worm-drive clamps were tolerable in the days of plain rubber hoses and dollar-a-pound CFC-12. When the industry switched to sophisticated multi-layer hoses, it needed much better.

Fair Questions

The technician will surely be thinking, “I can’t do helium mass spectrometry or anything like that in my shop. Is there something more practical? And anyway, if I use the equipment that I have, and hose labeled J2064, isn’t that enough? And if it isn’t enough for a J2064 label, why isn’t it okay for the real world, to stop a leak in a customer’s car, if it’s what I always used?”

Those are fair questions, and the basic answers are: The Service Team has been trying to figure out a way for shops to test a field repair. It is hoped that a new level of practical precision will be developed as a shop technique, and that a test with next-generation leak detectors will meet the SAE standard.

An occasional comeback is part of the business, and if the service technician made a few bad crimps in a year, it used to be the technician would just fix them. Now, the technician might be facing a legal question with a field repair, if he or she is in a state that decides to use SAE J2064 as a reference.

If the technician chooses to continue with field crimping, following are some suggestions for doing the job a lot better. The plain fact is that even if the equipment turns out to be capable of a J2064-compliant crimp, that doesn’t mean much if the technician is not following the specified procedure.

Practical Matters

We’re not blaming shops for all the issues of non-compliance. Sure, failure to maintain the crimper or using the wrong dies are correctible items. However, we have to admit that the “by the book” procedure is not one that is easy to follow. It includes making sure that the fittings and hoses are a within-tolerance fit, and that the crimp meets the dimensions specified.

If the technician is just cutting off the needed length of bulk hose, inserting the needed fittings and turning the crimper’s forcing screw until the joint seems “tight enough,” it’s unlikely to produce a J2064-compliant crimp.

A major issue is the hose, which has greater tolerances than the metal fittings. There are cases where the wrong-size fitting was inserted — so loose that if you inverted the hose, the fitting might drop off. Any crimp made would be pure guesswork. Some shops also believe “one crimper fits all” and use a hydraulic crimper on an A/C hose. That may produce a tight crimp, but it’s been known to crack the hose’s barrier lining. Further, although the beadlock has a triple-rib design, a triple-barb fitting with a crimping ferrule is not a suitable substitute, even if it seems to be a good fit in the hose.

The conscientious shop can do a much better job of field-assembly and repair. The by-the-book procedure adds just a few minutes to the job, but it does require a micrometer in the 0-1 inch range, with pointed tips to measure across the flats of triple-bubble crimp. In tests the Service Team used a conventional 0-1 inch micrometer to measure

the hose itself. Although the pointed-tip tool might be enough, the team found the conventional style more accurate for use on hoses.

Measure Twice, Crimp Once

Start with a quality brand of hose and a hose cutter that produces a neat end. Start by measuring the hose itself.

Measuring the wall thickness may seem like an unnecessary move, but if the technician compares the hose and the fitting, he'll see why it's important. Unless the hose wall thickness is within specs, the beadlock fitting's ferrule might not crimp the fitting's neck properly — overall diameter of the hose (which some specs quote) is not necessarily an adequate alternative.

The practical approach that the Service Team used is to find and insert a cylindrical ballpoint pen that is a moderately-tight fit into the hose, then measure the pen diameter and the hose diameter, both at the hose end. Subtract pen diameter from the hose outside diameter to get the thickness of two walls. Divide by two to get the individual hose wall thickness. Measure at two points around the circumference of the hose and pen to make sure both are round. Note: don't use a sharply tapered pen, for although it may go in and reach a tight fit location, the micrometer spindle won't make the flat-on contact on the pen right at the hose end, which is what is needed for an accurate reading. If all that's available to produce a moderately-tight fit in the hose is a gently-tapered pen or rod, insert it but use the pointed-tips micrometer, to make contact as close to the hose end as possible for maximum accuracy.



Cylindrical pen is a tight push-fit into the hose, so to determine hose inner diameter, measure the pen diameter at the hose end. The hose in this case is 13/32-inch nominal inner diameter size, (.406-inch), but the pen actually measured 0.416-inch.



Measuring the hose diameter produces a reading of 0.699 inch. Subtracting 0.416 inch leaves 0.283-inch, which, divided by two indicates a 0.1415 inch wall thickness.

If it meets the specs, the hose can be used. Be sure to measure the outside diameter at both ends of the needed length of bulk hose before cutting. Good hose should be within tolerance, not close to the limits. Don't try to make do with out-of-tolerance hose or by over-crimping the wrong-size fitting.

Note that the use of hose wall thickness vs. outside diameter is part of one manufacturer's system. Another manufacturer might choose outside and inside diameters for the specifications that help produce field-assembled hoses that meet J2064. And of course, there are alternatives to crimping.

Appearance Counts

Inspect the crimp for a good visual appearance. It should be uniform and the fitting itself should not be deformed. Oblong, out-of-round or irregular crimps usually indicate worn die carriers or a mismatch of the two dies. Finally, measure the diameter of the center crimp with the pointed-tip micrometer, at three roughly-equal points around the circumference. Total them and divide by three to get an average, which should be within the tolerance of plus/minus 0.012-inch.

Forget about the soap-bubble testing. That's good for about 50 oz/yr leakage rates at one bubble per second, not even so great in the CFC-12 days. After recharging and test-running the A/C, use a good electronic leak detector around the crimp joint to make sure.

Working Group 4: Develop HFC-134a Mass Balance for U.S. Mobile A/C Market

This group worked to identify and quantify the various emissions sources related to vehicle service, repair and end-of-life, then estimate potential emission reductions as improvements are developed and implemented.

Work initially focused on collecting the best available information and statistics to identify and quantify all refrigerant emissions related to mobile air conditioning.

Refrigerant Manufacturing
Manufacturing Process
Decanting (Who decants? How many steps involved?)
Mobile A/C System Manufacturing
Initial OE Refrigerant Fill
Mobile A/C System Normal Operation
"Normal" System Emissions
Accidental Release
Collisions Resulting in Refrigerant Loss
Professional Service and Repair
Recovery Efficiency
Filling Systems without Leak Repair
DIY Service and Repair
Charge Accuracy
Filling Systems without Leak Repair
End of Life Vehicles
Compliance Regarding Refrigerant Recovery
Recovery Efficiency
Handling of Recovered Refrigerant
Refrigerant Reclaimers
Refrigerant Released in Reclaiming Process
Refrigerant Released in Destruction Process
How Much Refrigerant Reclaimed/Destroyed?

The chart above lists incidents or procedures which could result in refrigerant emissions attributed to mobile air conditioning. The Service Team focused its efforts in the areas highlighted above.

A Close Look at the Service Experience

In the summer of 2005 the I-MAC Service Team conducted a survey of repair shops to better understand the types of air conditioning service and repair jobs being handled by independent shops.

The shops participating in this survey were located in Arizona, California, Florida, Ohio and Pennsylvania, and they processed 1,500 vehicles with A/C complaints from June 1 through August 31, 2005. The age of the vehicles spanned more than 60 years, ranging from a 1940 Ford Coupe to a 2005 cargo truck, but the repair jobs most commonly seen by independent repair shops continued to be 5 to 10-year-old vehicles. Half of the jobs involved vehicles manufactured from 1996 to 2000, but more than 30 percent of the

cars coming in for service were from the 1991 through 1995 model years. A respectable 10% of vehicles brought in for A/C service were older than 15 years.

Number/Percentage of Jobs By Model Year					
	No.	%		No.	%
1990	43	3.03%	2000	120	8.47%
1991	54	3.81%	2001	59	4.16%
1992	72	5.08%	2002	26	1.83%
1993	78	5.50%	2003	15	1.06%
1994	97	6.85%	2004	1	0.07%
1995	132	9.32%	2005	1	0.07%
1996	164	11.57%	1989 or Older		9.69%
1997	147	10.37%	1990 - 1995		33.59%
1998	146	10.30%	1996 - 2000		49.53%
1999	125	8.82%	2001 - 2005		7.19%

Most of the vehicles in this survey bore the badge of Detroit's Big Three. GM's representation was 38.5%, Chrysler's 21% and Ford's 20%. Honda, Toyota, Nissan and Volvo made a showing, in descending order, and even the elusive DeLorean and Rolls Royce occasionally popped up on repair orders.

In this survey, 73% of the vehicles brought in for service were originally manufactured with HFC-134a systems. Another 7% of the vehicles had already been retrofitted to HFC-134a when they came in for service, and the shops we surveyed retrofitted an additional 1% of the vehicles. The remaining 19% still had CFC-12 systems when they left the surveyed shops.

Eight Collection Sites in AZ, CA, FL, OH and PA	No.	%
Collection Period: June 1 to August 31, 2005		
Number Jobs Requiring R&R	1,181	79.96%
HFC-134a Vehicles	1,081	73.19%
Vehicles Previously Retrofitted to HFC-134a	97	6.57%
Retrofits from CFC-12 to HFC-134a Performed This Period	16	1.08%
CFC-12 Vehicles	274	18.55%
Contaminated Systems	9	0.61%
Total	1,477	100.00%

Looking at percentages of parts replaced, compressors came in at number one with 19%. Evaporators and accumulators were both about 12%. Condensers were fourth with 10%, hoses about 9%, orifice tubes 9%, driers 8%, TXV's 5%, etc.

Major Components Replaced					
Compressor	252	19.08%	Total Jobs	1,477	
Evaporator	158	11.96%	Part Replaced	1,321	89.44%
Condenser	129	9.77%	No Part Replaced	129	9.77%

One shop in the survey tracked number of leaks found in the diagnostic process and how many customers chose not to have the leaks repaired. The shop recorded 230 jobs total in the survey period. Customers refused further service on almost 25% (56) of the A/C systems found to be leaking at this shop. Approximately 9% of the 230 jobs are not reflected in the categories below. Identification of the specific problems related to those systems are not clear from the raw data.

Parts Replaced		
Accumulator	21	9.13%
Belt	6	2.61%
Compressor	29	12.61%
Condenser	22	9.57%
Electrical	4	1.74%
Evaporator	18	7.83%
Hose Assembly	25	10.87%
Receiver Drier	13	5.65%
Switches	8	3.48%
Valves	9	3.91%
Total	155	67.39%
Leaks/Seepage Found, Customer Chose Not To Have Repaired		
Leaks Found In Accumulator	1	
Leaks Found In Compressor	26	
Leaks Found In Condenser	9	
Leaks Found In Evaporator	20	
Total	56	24.35%
Customers Asked To Return For Check After Interval	10	
Customers Who Did Return For Check After Interval	3	
Customers Who Did Not Return For Check After Interval	7	

One objective of the survey was to get a better idea of how much refrigerant is recovered and recycled at service. One of our respondents actually kept records of the amount of refrigerant recovered from jobs in that shop, and averaged about four ounces per vehicle. (This shop recorded that 65% of vehicles arriving for service were virtually empty. The remaining 35% had charges ranging from a low of 0.25 pounds to a high of 2.25 pounds.) Another collaborator estimates that about 20% of the refrigerant his shop uses is recovered and recycled. (Caution: Given previous data provided in this report, any estimates of refrigerant recovered by the current generation of recovery equipment is suspect, since recovery is likely incomplete, and the machine scales used to measure the recovery are suspect.)

Sources of Refrigerant Emissions During A/C Service, Vehicle End-of-Life

- **Miscellaneous emissions during/after system service**
 - These are defined as HFC-134a leaks or emissions that occur during service, or if an improper service or repair is performed.
 - Sources of emissions:
 - No or improper recovery

			Recoveries Per Year	Recoveries Per Year
			20,000,000	25,000,000
	%	Ounces	Emissions	Emissions
Average System Charge	1.00	28.00	Lbs./Year	Lbs./Year
Refrigerant Not Recovered	0.30	8.40	10,500,000	13,125,000
	0.25	7.00	8,750,000	10,937,500
	0.20	5.60	7,000,000	8,750,000
	0.15	4.20	5,250,000	6,562,500
	0.10	2.80	3,500,000	4,375,000
	0.05	1.40	1,750,000	2,187,500
"...an estimated 20 to 25 million automotive A/C systems are serviced annually..."				
<i>Increasing Summer Profits with A/C Work, Larry Carley, Brake & Front End, 3/2005</i>				

The chart above reflects the amount of refrigerant potentially lost at service, based on the percentage of refrigerant not recovered from the system.

- System is "topped off" rather than repaired
- Improper diagnosis and repair
- Faulty replacement component
 - Including "shop fabricated hose assemblies"
- Losses from disposable containers – 30# cylinders and 12 ounce cans

		Cylinders Per Year
		1,100,000
	Pounds	Emissions Lbs./Year
30 Pound Cyl.	30.00	
Heel Remaining	0.0430	47,300
	0.1200	132,000
	0.2600	286,000

			Cans Per Year
			35,000,000
	%	Pounds	Emissions Lbs./Year
12 Ounce Cans	1.00	0.75	
Heel Remaining	0.013	0.0098	341,250
	0.018	0.0135	472,500
	0.019	0.0143	498,750
	0.075	0.0563	1,968,750
	0.100	0.0750	2,625,000

The charts above reflect the amount of refrigerant represented by various size "heels" remaining in non-returnable refrigerant containers.

			A/C Jobs Per Year	A/C Jobs Per Year
			20,000,000	25,000,000
	%	Ounces	Charge	Charge
Average System Charge	1.00	28.00	Lbs./Year	Lbs./Year
Recharge All Systems			35,000,000	43,750,000
	Lbs./Year			
Sold in 12 Ounce Cans	26,250,000			
Sold in 30 Pound Cylinders	33,000,000			
Total Sold in 2004	59,250,000			
For June 1992, Industrial Market Research reported that 11% of the fleet was repaired, amounting to 21.1 million vehicles requiring 42.2 million pounds of CFC-12				
<i>Mobile Air Conditioning Systems and the Environment, Ward Atkinson and Jim Baker, May 2002</i>				

This chart reflects the amount of refrigerant sold into the mobile air conditioning aftermarket in 2004, a total of 59,250,000 pounds. This is approximately 15.5 million pounds more than would have been required to fully charge an estimated 25,000,000 vehicles which were professionally serviced, and this does not take into account the amount of refrigerant recovered, recycled and reused.

- Losses at vehicle end-of-life

	Average		30% Have Charge	40% Have Charge
	Charge	Vehicles	Potential	Potential
	Remaining	Scrapped	Emissions	Emissions
Average Remaining Charge	Pounds	Annually	Lbs./Year	Lbs./Year
Vehicles Scrapped Annually	1.00	12,000,000	3,600,000	4,800,000
Studies done in New Jersey and California suggest that 30% to 40% of vehicles arriving at end of life have an average refrigerant charge of one pound in system.				

This chart reflects an estimate of the amount of refrigerant available for recovery at vehicle salvage.

- **Recommendations:**
 - Recovery and recycle is required by U.S. law and should be practiced by all repair shops and enforced by regulatory agencies.
 - System leaks should be identified and repaired.
 - R/R machines should be maintained in good working condition to avoid excessive refrigerant loss during the periodic air venting from the recovery tank.
 - Leak limits should be identified for replacement components.
 - A higher level of training on proper repair and diagnosis and reinforcing responsible refrigerant use should be encouraged throughout the service industry.

- As required by U.S. law, salvage operations should recover all refrigerant before the vehicle is scrapped.
- Federal and local regulators should also play an increased role by enforcing regulations that are already in place to minimize emissions.

Working Group 5: End-of-Life (EOL) Vehicles

This group has researched and tentatively quantified potential emissions from EOL vehicles. There are indications from several studies and reports that, while refrigerant recovery from EOL vehicles is required by regulations, compliance with regulations could be improved. Research by another group within the I-MAC Service Team also suggests that recovery of refrigerant from EOL vehicles is particularly difficult, since engine heat cannot be used to enhance recovery, and recovery is likely to occur in ambient temperatures not conducive to full system recovery. The Service Team contacted management of the Automotive Recyclers Association (ARA) to open a dialogue about how refrigerant recovery at EOL can be improved, and how the team could assist. The team drafted an article about the importance of EOL refrigerant recovery which was published in 2006 in ARA's trade publication. ARA has cooperated in this effort by assisting with communications and research. Work is ongoing to achieve the goal of reduced emissions in this sector.

In a report on "Management of End-of-Life Vehicles (ELVS) in the U.S.,"¹ the authors estimate that 94% of ELV vehicles are recycled each year, while the remaining six percent are abandoned, falling outside the existing end of life vehicle management infrastructure. This represents 12.5 million vehicles (7.7 million cars, 4.6 million light trucks and 0.2 million medium/heavy duty trucks) recycled each year, while 0.8 million (0.5 million cars and 0.3 million trucks) are abandoned.

The study notes that auto dismantlers consist of two distinct types:

- High-value parts dismantlers (high volume, quick turnover operations targeting late-model vehicles.
- Salvage/scrap yards (low volume, slow turnover operations accepting most vehicles.
- Included in the EOL process are so-called "gypsy operations" (unregulated, small operations) that do not follow industry procedures of reclaiming chemicals from scrapped vehicles.

Estimates of refrigerant available for recovery at vehicle end of life vary.

The California Air Resources Board cites several different assumptions and estimates including a U.S. EPA Vintaging Model which assumes an average recovery at scrapping equal to 57% of the capacity of the A/C system, and a survey by CARB which yielded a mean recovery rate of 17% of capacity.²

¹MANAGEMENT OF END-OF-LIFE VEHICLES (ELVS) IN THE US

Jeff Staudinger and Gregory A. Keoleian, Center for Sustainable Systems, Report No. CSS01-01, University of Michigan, Ann Arbor, Michigan, March, 2001, pgs. 5, 14.

²http://arb.ca.gov/cc/factsheets/support_hfc.pdf

HFC-134a as an Automotive Refrigerant -- Background, Emissions and Effects of Potential Controls, California Environmental Protection Agency Air Resources Board, July 21, 2004

On December 24, 2004, the Japanese Ministry of the Environment released survey results on the recovery of fluorocarbons from car air conditioners (class-2 specified equipment) collected in fiscal 2003 in accordance with the Law Concerning the Recovery and Destruction of Fluorocarbons (Fluorocarbon Recovery and Destruction Law).

About 638 tons of fluorocarbons were recovered from car air conditioners in fiscal 2003. About 1.7 million car air conditioners were recovered from the estimated 4 million cars scrapped during the fiscal year, indicating a collection rate of around 42 percent based on the number of air conditioners. Meanwhile, the amount of actual fluorocarbons recovered is estimated at 23 percent of the refrigerant originally loaded into the air conditioners during manufacture (assuming 700 grams per car).³

In another study by Auto Recycling Nederlands, it was found that end-of-life vehicle recovery of refrigerant was between 34% and 38% of the initial charge.⁴

At the invitation of the American Recyclers Association's executive vice president George K. Eliades, MACS (representing Team Four) attended the group's 63rd annual Convention and Trade Show in downtown Indianapolis in late September, 2006.

ARA is the recycling industry's trade group. It has members in 12 countries, and represents about 1,000 of the estimated 7,500 legitimate U.S. recyclers.

The organization strongly supports pending federal legislation to establish a VIN database of total-loss vehicles, and has developed a protocol and guidelines to establish a national standard for handling, shipping and storage of OEM non-deployed airbags. ARA has also spearheaded the voluntary nationwide program to remove and recycle mercury switches, keeping them out of landfills.

Members of any trade organization usually represent the industry's brightest and best, the people who realize the value of what a group can accomplish. ARA promotes both its Certified Automotive Recycler (CAR) and Gold Seal programs to members and to the public. The CAR program requires a facility to comply with guidelines and requirements for Business Practices, Environmental Issues, Safety, and Licensing-Regulatory matters before certification is issued. The Gold Seal program encourages excellence in customer service, accurate part descriptions, reliable deliveries and written product warranties.

For perspective, vehicle recycling is a \$25 billion per year business according to independent statistics, and it is rated as the 16th largest business segment in the

³<http://www.japanfs.org/db/1023-e>
Japan for Sustainability

⁴Consultation Paper for European Commission Directorate-General Environment: How to Considerably Reduce Greenhouse Gas Emissions Due to Mobile Air Conditioners, February 2003

country. ARA studies show that U.S recyclers employ more than 46,000 people and make significant economic contributions to their communities.

The ARA Convention and Trade Show, attended by 800 members and vendors, offered several classes and seminars as well as product offerings and sales opportunities for every facet of the industry. Casual conversations usually begin, “Hi, do you own a yard?” and an outsider is quickly educated.

“The environmental laws of the ‘70s and ‘80s changed this business for the better, and in the ‘90s the Internet changed it a lot more. I don’t have to sell locally now; I can ship parts all over the country and find what I need in somebody else’s yard, too,” said a second-generation recycler from New York. Several e-business providers were competing for yard owners’ business, offering real-time parts and salvage auctions, sales outlets, shipping consolidation and other services.

The facilities owned by ARA members are no longer the town junkyard with random piles of parts and vehicles everywhere. The yards MACS saw, in pictures and in person, rivaled any mall parking lot for neatness and order. Most are family owned, often by third or fourth generations. A medium sized yard might encompass 60 acres and hold 1000 cars neatly arranged in aisles and rows.

Many operators rotate their stock every 45-90 days, but others still have cars from the 1940s. “Some guys have been buying parts off the same car for years,” a rural Montana operator told MACS. “Last year a bumper, today a generator. I have a lot of old farm equipment too, that’s keeping other old equipment running.” It all depends on knowing your market.

On arrival at most yards, a damaged vehicle – often bought from an insurance company – immediately has all its fluids drained (sold to re-processors or used in company vehicles), catalytic converters removed (sold for reclamation), and refrigerant recovered (sold to reclaimers). Fuel tanks, airbags and batteries are removed, and usually wheels.

“I can’t think of a more regulated segment of the auto industry,” another yard owner told MACS. “We are regulated by the Feds, the state, and the local government. I have to be concerned about groundwater and runoff, haz-mats, tires, batteries, fluid recovery, OSHA, EPA and a thousand other things. I can’t afford to be sloppy.”

Another attendee said, “About 90% of ARA members do the right thing environmentally – recover, recycle, etc. In the greater industry, it might be about 70-80%.” Another delegate added, “When (yards) don’t recover fluids or refrigerant, they’re throwing money away. You can sell that stuff!”

The business model of each recycling yard varies. Some will strip the usable parts for local resale, perhaps to body shops, insurance companies, other yards or walk-in customers. It’s not uncommon to see neat racks of wheels, doors, tailgates, and

bumpers awaiting sale, and some facilities have indoor warehousing for mechanical parts, engines, and transmissions.



If reuse isn't an issue, simple refrigerant recovery tanks – like these from WEN Industries – are sufficient in many facilities. Additionally, many yards now use refrigerant identifiers before hooking up collection equipment.

One trend in the industry is the rise in pull-your-own-part yards, where a customer removes the part from the vehicle, then pays on the way out. An owner of large family-run yard said, "Our business is about 90% retail and we try to keep it simple. Most of our you-pull-it customers are Joe Driveway; they are just trying to keep an old car going."

Others operators opt for going direct-to-scrap. After recovering the fluids and refrigerants (the value of which sometimes covers the initial purchase of the car), the vehicles are "logged" or "baled" and sent to a shredder. Simple crushing or flattening isn't common any more; sophisticated hydraulic compacters can now reduce a full-size sedan to about the size of a queen bed in 90 seconds. The procedure is impressive to watch.



The mobile compactor reduced a Malibu to the size of a large bed in under two minutes. The tightly packed bale, compacted to 40-80 lbs. per cubic foot, stacks easily and safely for transport to a shredder.

It's a demanding business, with high start-up costs and a large annual insurance bill, but a lucrative one for those who master it. The secret is found in the yard's efficiency. In most cases, the scrap buyer or re-processor pays for weight or volume, not by the item. For example, a recent industry publication showed the average price for crushed auto bodies at about \$128 per ton, and \$145 per ton for unstripped engines. At those rates, you have to pull a lot of engines and move a lot of tonnage to cover costs and make money, but it can be done.

Saving time on each car is important, and equipment manufacturers provide many different lift racks, machines and transporters to aid the task. It was mentioned in one seminar that an efficient yard could move a car from "door to door-stop" in 30 minutes.

There is a market for almost everything if you choose to remove it. At the trade show, several companies wanted to buy various scrap products generated during dismantling, including fuels, lubricants, wheels, and mechanical cores such as compressors, alternators, water pumps and fuel injectors.



Time is money. This specialty rack allows simultaneous collection of several fluids under the car. The hydraulic shears are used to cut off catalytic converters. After being stripped and drained, cars are moved around the yard by the specialty forklift in the background.

One buyer whose company manufactures pipes used in underground water treatment systems was there just to develop sources for front and rear plastic bumper covers. “Normally, the damaged ones go into the landfill, but I’ll buy them. They have the right plastics for our products,” he said.

After reinventing itself a generation ago, the vehicle recycling industry continues to change as new markets emerge. Some of their challenges are common to any business—hiring and keeping good employees, training, safety, business development, customer service. Based on our experience, ARA members are meeting the challenges every day, improving their public image, improving the industry, and protecting the environment.

Working Group 6: Communication, Education, Outreach

MACS has worked to inform and educate the industry about the importance of refrigerant emission reductions through its technical publications and magazines, through its website, through other automotive associations, through the consumer and trade press, through a series of 60 clinics presented to industry technicians throughout the U.S. each year (2005 – 2007), through national and international automotive trainer organizations and through presentations to industry technicians in large national and international forums.

Articles Published in MACS Service Reports

May 2007

"Phantom Repair?" -- Not Really, pgs. 7-8

April 2007

New SAE Standards for A/C Are Coming, pgs. 1-3

February 2007

A/C And Its Effect On Fuel Economy, pgs. 3-4

European Cars -- The Prospects, pg. 5

January 2007

The Legal Issues, pg. 1

The New R/R/R Machines Are On The Way, pgs. 1-4

SAE J2788 -- What It Says And Means -- A Summary, pgs. 4-6

The Real World -- What You Can Expect From The Equipment, pgs. 6-7

A New Machine By The Numbers, pgs. 7-8

April 2006

Concerned About Those New Refrigerants?, pgs. 1-2

No. 1 Problem: Accurate Charge, pgs. 1-8

February 2006

Have Patience! You May Need It For Leak Detection, pgs. 5-6

False-Triggering A/C Refrigerant Leak Detectors, pg. 6

July 2005

I'm Not Into The Global Warming Thing, pg. 2

Why You Can't Find The Leak, pgs. 2-8

June 2005

Sight Glasses And More: Charging HFC-134a Systems, pgd. 1-3

Recovery And Charge Accuracy: A New SAE Standard Is Coming, pgs. 3-5

April 2005

Standards And Practices: What's In It For You?, pgs. 1-5

February 2005

Why Does Anyone Want To Replace HFC-134a?, pgs. 1-2

How It Could Be Done, pgs. 2-5

Close-Up On What The Technician Faces, pgs. 6-8

January 2005

The Fat-Free Hot Dog: A Refrigerant Allegory, pg. 1

Articles Published in ACTION Magazine

May 2007

Hard Choices Ahead Next Four Years (New Refrigerants), pgs. 20-24

Field Assembly Clinic (Coupled Hose), pgs. 38-42

Many Questions, Few Answers (Alternate Refrigerants), pg. 62

March/April 2007

State Of The Industry, pgs. 59-60

January/February 2007

New Life At The End Of The Line (ELVs), pgs. 46-48

A Sea Change...Again...And Again (I-MAC), pg. 70

November/December 2006

Two Sides To Every Ocean (I-MAC), pg. 70

September/October 2006

How Much? How Long? (I-MAC Update), pg. 14

SAE IN Phoenix: The 2006 ARS Symposium, pgs. 20-28

July/August 2006

By The Numbers, pg. 62

May 2006

Refrigerant Reclamation, pgs. 14-15

Another Future? (Europe), pgs. 17-20

March/April 2006

SAE Committee Meets, Reviews New Standards, pg. 52

Practicing What You Preach (I-MAC Update), pgs. 57-58

January/February 2006

Improving Mobile Air Conditioning Systems Globally, pgs. 52-56

November/December 2005

Finding And Fixing The Leaks, pgs. 54-55

September/October 2005

Recovery And Recharge Accuracy, pgs. 38-39

July/August 2005

Lessons To Be Learned, pgs. 8-9

I-MAC 30/50: Year One, pgs. 60-62

May 2005

At The Summit, pgs. 42-45

The Real World, pg. 62

January/February 2005

Europe Decides, pgs. 22-23

Information and education promoting the necessity for reduction of refrigerant emissions during A/C service operations, and "how to" technical methods and procedures were incorporated in A/C Update Training done by MACS in annual clinics conducted in the spring of 2005, 2006 and 2007. In each year, 65-70 training clinics were conducted.

2005 Mobile A/C Update Clinic Book

Introduction Of Alternative Refrigerants, HFC-134a Emission Reduction, pgs. 70-83

2006 Mobile A/C Update Clinic Book

Recovery, Leak Detection, Charging, pgs. 6-19

2007 Mobile A/C Update Clinic Book

Recovery/Charging Equipment, Alternative Refrigerants, Charging, Leak Detection, pgs. 17-23, 26, 30-32

MACS Website

MACS incorporated an I-MAC button on its website, building pages independently and linking to pages relating detailed information about I-MAC.

Improved Mobile Air Conditioning Web Publication Strategy

MACS developed and proposed a strategy for building public awareness of the I-MAC effort.